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BRITISH WATER WORKS PRACTICE

BY JOHN BOWMAN*

[*Read September 14, 1939.*]**

It was arranged some years ago that the writer should visit the New England Water Works Association in 1939 and deliver a paper. The subject chosen is "British Water Works Practice" and the object of the paper is to present in brief a general outline of British Water Works Practice throughout Great Britain.

It is hoped that the information contained in the paper will be of interest to American Water Engineers as forming a basis of comparison between practice in the New England States and in Great Britain.

Geography and Hydrology. Great Britain occupies geographically a supremely favoured position on the face of the earth. It is situated in the Northern Temperate Zone which excludes it from the perpetual extremes of cold or heat of the Arctic or Torrid Zones. Further it is comparatively narrow throughout and is subjected in almost every part to the temperature from the encircling sea. This encircling sea is continuously subject to the influence of that amazing phenomenon, the Gulf Stream, which finds its way across the Atlantic from the Gulf of Mexico to our shores and tempers the whole atmosphere. The severe long winters and the hot dry summers which are experienced in lands in the same latitudes in America and the continents of Europe and Asia are unknown to us.

The configuration of the island of Great Britain is such that from North to South there is a continuous range of mountains which form a backbone to the island. Almost the whole of Scotland is mountainous. Wales also is mountainous and throughout England the Pennine Chain and the other hills run from north to south and cover the western half of the kingdom. Towards the east and southeast the land slopes away into the flat lands of the eastern and southeastern counties. The highest mountain in Great Britain is 4,406 ft. above sea level and there are few mountains that are more than 3,000 ft. high.

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**Editor's Note: Outbreak of war prevented Mr. Bowman from presenting this paper in person.

FIG. 1—BRITISH ISLES. OROGRAPHICAL MAP.

The rainfall is variable. Over the whole area of 121,000 sq. miles of Great Britain the average rainfall of the very wet year of 1872 was 56.7 in. or 37 per cent. above the average, while in the dry year of 1887 the average rainfall was 31.8 in. or about 77 per cent. of the average. The normal annual rainfall of England is 32.67 in., Wales 50.14 in. and Scotland 50.32 in. In certain parts of Scotland and

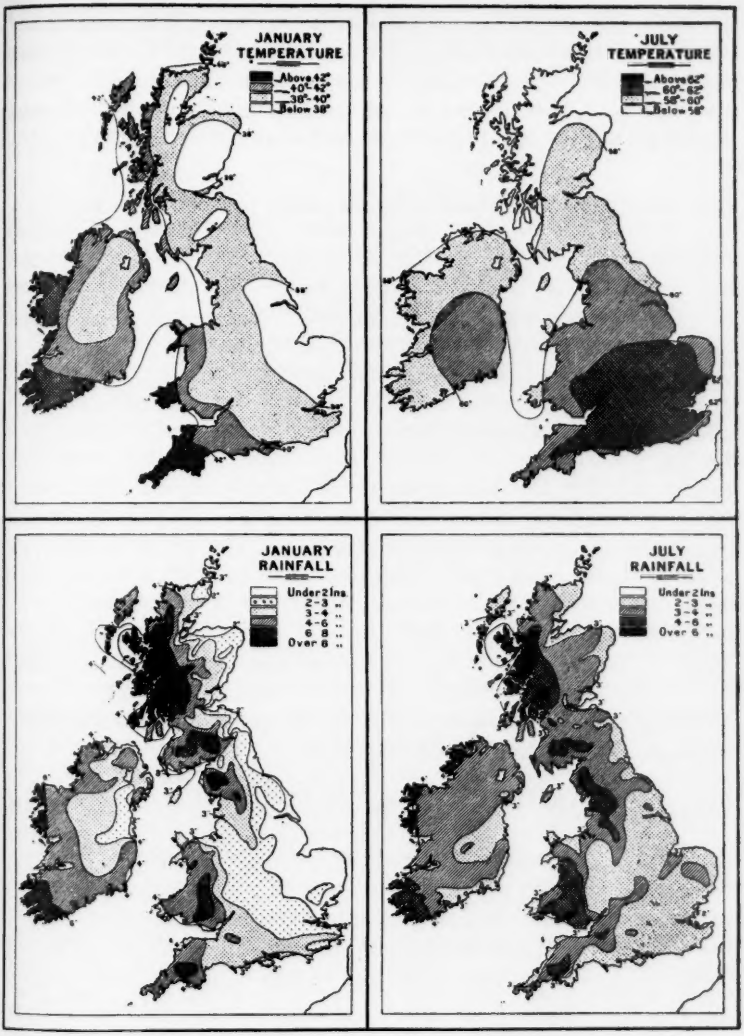

FIG. 2—BRITISH ISLES. CLIMATIC MAPS.

Wales the rainfall is very much higher rising to as much as 200 in. or more.

Intense droughts and heavy rainfalls in short periods of time

are rare. The rainfall is comparatively uniform. Thus in England and Wales during the period of 35 years from 1881 to 1915 the average number of rain days was 188 in England, in Scotland 217 and in Ireland 220. Table 1 shows the general monthly and annual averages of rainfall and the mean number of rain days during the period 1881 to 1915.

TABLE 1—MONTHLY AND YEARLY AVERAGE RAINFALL AND NUMBER OF RAIN DAYS, 1881 TO 1915.

	ENGLAND AND WALES		SCOTLAND		IRELAND		BRITISH ISLES	
	In.	Days	In.	Days	In.	Days	In.	Days
January	2.99	18	4.90	20	4.07	20	3.78	19
February	2.57	15	4.18	18	3.53	18	3.26	17
March	2.67	16	4.05	19	3.36	19	3.22	18
April	2.12	14	2.99	16	2.75	17	2.52	15
May	2.30	14	3.01	16	2.75	16	2.61	15
June	2.44	13	2.83	15	2.82	15	2.64	14
July	2.87	14	3.78	18	3.37	18	3.25	16
August	3.35	16	4.51	19	4.20	19	3.88	17
September	2.54	13	4.00	17	3.13	17	3.09	15
October	3.97	18	4.90	19	4.08	19	4.25	19
November	3.49	18	5.29	19	4.28	20	4.19	19
December	3.92	19	5.88	21	4.96	22	4.72	20
Year	35.23	188	50.32	217	43.30	220	41.41	204

Heavy rainfall in short periods are not common. Table 2 shows the frequency of rainfall in short periods.

TABLE 2—FREQUENCY OF INTENSE RAINFALLS.

	5 Min. In.	10 Min. In.	15 Min. In.	20 Min. In.	30 Min. In.	45 Min. In.	60 Min. In.	90 Min. In.	120 Min. In.
Once a year	0.18	0.23	0.28	0.31	0.36	0.41	0.46	0.52	0.58
Once in 2 yrs.	0.24	0.31	0.36	0.40	0.46	0.52	0.58	0.66	0.72
Once in 5 yrs.	0.33	0.43	0.49	0.55	0.62	0.71	0.78	0.88	0.98
Once in 10 yrs.	0.43	0.54	0.62	0.68	0.77	0.88	0.97	1.10	1.20
Once in 20 yrs.	0.54	0.68	0.78	0.85	0.97	1.10	1.20	1.36	1.47
Once in 40 yrs.	0.68	0.85	0.97	1.06	1.19	1.35	1.48	1.67	1.82
Once in 160 yrs.	1.06	1.31	1.49	1.61	1.82	2.06	2.24	2.52	2.73

Compare these with the rainfall of Germany where rainfalls of from 2.76 to 3.14 in. in 120 minutes are not uncommon.

Evaporation is not so heavy as in other countries in the same latitude. It varies from 11 to 17 in. per year, the average being 14 in.

It will thus be seen that the climatic conditions prevailing in Great Britain are unique; the rainfall is more evenly distributed, the intensities being less and evaporation is not so great as in countries of the same latitude in other parts of the earth.

History of Water Supplies The development of systematic water supplies is comparatively modern, not more than a century old. London, it is true, had the New River Company in 1613, and other companies were founded round London before 1798. Liverpool had a water company in 1799. Edinburgh had a municipally-controlled undertaking in 1676, although later the affairs passed into the hands of a company. Generally speaking, however, it was not until about 1845 that proper water supplies were introduced into towns and in many cases, in fact in most cases, none of these towns had any drainage system whatever. Most municipalities and authorities owe the introduction of water supplies to the energy and enterprise of private companies. These companies gradually became municipally-owned but today there are still some large areas operated by companies and very efficiently they are administered. The profits are limited by Act of Parliament to 6 per cent. of the capital. The whole of London was up till 1903 supplied by eight companies who supplied each approximately one million inhabitants. These companies are now merged in the Metropolitan Water Board which is publicly administered, and the population supplied is approximately eight millions, five of whom are on the north side of the Thames River and three million on the south. The supplies of most of the large towns in Great Britain are now municipally owned. There are no companies supplying water in Scotland or in Wales.

Sources of Water Supply. There are 108 towns in England with a population of 50,000 and more. Twenty-six of these draw their supplies from rivers; twenty-seven are supplied from upland surface sources; thirty from underground supplies and twenty-five from mixed sources. The population supplied in these towns is 22,432,000, allocated as follows:

TYPE OF SUPPLY	POPULATION
River supplies	7,307,000
Upland surface	7,568,000
Underground	5,557,000
Mixed supplies	2,000,000
Total	22,432,000

The figures are approximate and rather misleading. The river supplies are to a population of 7,307,000 but of this 6,528,000 is that proportion of London and the surrounding burghs and district which use river water. Leaving out London it will be seen that in England the largest proportion of water is from upland surface waters. In Scotland almost all the water, except Aberdeen and Perth which have river supplies and some towns on the northeast coast supplied from springs, is from upland surface sources. Wales is chiefly supplied from upland surface water although one or two places are supplied with spring water.

The upland surface waters are impounded in reservoirs usually holding from 180 to 200 days supply of the average daily yield. All of the older dams were of earthwork with waste weirs constructed clear of the dams to take away the flood waters. The first masonry dam to be constructed of any magnitude was that of the Vyrnwy Dam for the Liverpool Waterworks. Since then masonry dams have been constructed for Birmingham, Derwent Valley and elsewhere. Generally speaking the tendency is to construct masonry rather than earthwork dams. There has just been completed in Scotland a dam which is of earthwork for about a third of the length at each end with the centre a masonry dam with a crest forming a spillway. The forming of a circular or bellmouth spillway instead of a crested weir has been adopted in some of the reservoirs constructed within recent years. A paper has already been presented to your Association on the subject of British Waterworks Practice dealing very fully with this side of the question.

Compensation Water. No reservoir can be constructed without Parliamentary Powers and no reservoir can be constructed without compensation being made to those who might be considered to suffer loss owing to the abstraction of the water for the supply to the town or area which the reservoir is intended to serve. Parliamentary practice has been to award compensation in the form of a constant quantity of water usually assessed at one third of the average available yield. Sometimes the compensation is much higher. In Edinburgh a reservoir constructed one hundred and twenty years ago must discharge nearly 2,500,000 U. S. gallons daily although the available draw-off to the city from this source is only little more. On another Edinburgh area, where an average of 5,400,000 U. S. gallons are abstracted from springs, compensation reservoirs have been constructed to supply the streams and from these nearly 10,000,000 U. S.

gallons are discharged daily, but as already indicated the usual compensation is one-third of the estimated mean flow. About the question of compensation there has been much discussion and in many cases grave dissatisfaction. In a recent report by the Central Advisory Committee set up by the Ministry of Health it is suggested that Parliament should be recommended to consider whether the time has not come for the existing practice regarding compensation water to be revised.

Underground Water. If the position regarding the control of surface water is unsatisfactory, still more so is that regarding underground water supplies. Local authorities and water undertakings are controlled so far as abstraction of underground water supplies is concerned but any private individual owning any land may sink wells without any permission and may abstract water for any purpose "including sale or disposal to others or for opening up a flow of underground water which he does not require". The position is very unsatisfactory. The whole question of planning underground and surface supplies is receiving the attention of the Central Advisory Committee, and already two reports have been issued. It must be admitted, however, that the task is a difficult one.

Another matter being dealt with by the same Committee is the consolidation of existing laws regarding water supply. The Waterworks Clauses Acts of 1847 and 1863 are the foundation of all existing local and special Water Acts. A Draft Bill has already been prepared and issued. This Act if passed would supersede all existing Water Acts. It aims at abolishing cumbrous compulsory legal procedure, for combining existing areas and for protecting and purchase of land where necessary.

Purification of Water. The Acts of 1847 and 1863 imposed on all water authorities the duty of providing the consumers in their area with a supply of "pure and wholesome" water. It may be said at once that the standard of water supplied throughout Great Britain has been consistently good. Where water is drawn from unpolluted areas and is stored in large reservoirs it may be supplied without any treatment whatever. Glasgow, the second largest city of the British Empire, draws 90,000,000 U. S. gallons daily from Loch Katrine and delivers it into the houses in its natural state. The supply has been in existence for over eighty years with not a single case of waterborne disease. With this exception nearly all large cities such as Liverpool, Birmingham, Sheffield and Leeds in England and Edin-

burgh in Scotland bring water from great distances and draw it from unpolluted sources but in addition filter the water. London draws its huge quantities from the rivers Thames and Lea. The researches of Sir Alexander Houston demonstrating the effect of storage on water has led to the Metropolitan Water Board constructing huge reservoirs on the Thames and Lea Works. In these, the water is stored for many months before it is passed on to the open sand filters. For many years it was the custom after storage and filtration to pass the London water into the mains without further treatment, but now the whole of the water is chlorinated as well.

An admirable paper was presented this year to our Institution on the trend of modern practice in water purification and the conclusion the author arrives at is that there is an increasing tendency to apply to all waters whether drawn from upland or underground sources some bactericidal agent, usually chlorine, but sometimes ozone. It is unlikely that such treatment will be applied to water which comes from unpolluted sources and which is filtered, but storage and filtration may not be wholly satisfactory if gathering areas are small or liable to contamination even though the water be stored and filtered. Chlorination or ozonisation is also being applied to underground water supplies liable to pollution. The recent Croydon epidemic, though entirely due to avoidable circumstances, has caused a great deal of anxiety to the government authorities and medical officers of health.

Consumption of Water. The consumption of water per head per day in Great Britain is very low compared with American cities. The consumption of water per head per day in England is low compared with Scotland. Taking six of the largest areas in England the consumption per capita per day is:

CITY	DAILY PER CAPITA CONSUMPTION U. S. GALLONS
Manchester	49
London	44
Liverpool	42
Leeds	40
Birmingham	37
Sheffield	37

Taking the six largest Scottish Authorities in order of consumption in U. S. gallons per head per day is as follows:

CITY	U. S. GALLONS
Paisley	98
Stirlingshire & Falkirk	71
Edinburgh	64
Dundee	60
Aberdeen	54
Glasgow	46

The first five towns include water for commercial as well as domestic purposes. That for Glasgow is for domestic purposes only.

It will be seen that while Scottish towns have much higher consumptions than English towns these fall far short of American towns. It is difficult to say why these differences exist. The standard of sanitation in Scotland was for many years in advance of England in respect that more houses had water closets and hot-water systems in Scotland than in England. This is not altogether a satisfactory explanation. Certainly the more modern a house is, the more water will be used. A very large percentage of houses in Great Britain has no bathrooms. These are old houses. Large portions of the population of Great Britain at the end of the war lived in appalling housing conditions. Since that period every city and burgh and local authority has embarked on housing schemes of great magnitude with the result that gradually the working class population is being housed in houses with water closets and baths and hot and cold water systems. Excellent as the progress of rehousing has been there is still a good deal of work to be done before every Briton has a house of the higher standard.

Standardisation of Water Fittings. Up to a comparatively recent period there was no standard for water fittings. Some towns had a very high standard. Others accepted almost any fitting. As a result of keen competition among manufacturers, the market was flooded with inferior taps, valves and water-closet ballvalves, all of which soon became in a state of disrepair with a resultant great waste of water. Water authorities generally possess ample power under the Waterworks Acts to deal with waste of water, but rigid inspection is expensive. The real remedy is to install good fittings at the outset. A Committee of the British Waterworks Association to deal with Water Bye-laws and the Standardisation of Water Fittings has been working for many years on this work. This Committee has produced a standard set of water bye-laws with specifications for pipes and fittings which has been adopted by many large Authorities. Representations were made that the Bye-laws and Specifications were unduly

stringent. Thereupon the Ministry of Health issued another set of Bye-laws with Specifications. The difference between the B.W.A. and M.O.H. standards is that the fittings specified in the latter are slightly lighter and no weights are specified as in the B.W.A. The position is not a good one. Some towns have one standard; some the other. There is hope, however, that soon a standard tap will be adopted to take the place of the two standards and this will be followed in time by other uniform specifications. When this is achieved it will be a benefit to Water Authorities, to consumers of water and also to manufacturers of fittings who at present have to manufacture two types of all fittings.

Pipes and Pipe Lines. Up to within recent years all pipe lines were of cast iron, vertically cast, with standard sockets and coated with Angus Smith's composition. Steel pipes were not generally favoured chiefly because of suspicion with regard to coating and lining. With the introduction of bituminous lining and sheathing, the use of steel pipes is now much greater, especially for large pipes where a jointer can enter the pipe and make a continuous bituminous joint to link up the lining of the two lengths. Cast-iron pipes are still, however, very largely used for distribution piping. Where these are being replaced they are being replaced up to 24 in. in diameter by spun-iron pipes. The centrifugal lining of iron pipes with cement and then dipping in bituminous solution is a further improvement in manufacture. This pipe is regarded by many engineers as the ideal pipe for ordinary distribution piping. Asbestos-cement pipes are also being used to a considerable extent for pipe lines of smaller diameter where conditions are suitable. These pipes are jointed with collars having rubber rings. For piping in houses, iron or steel pipes are seldom used. Up till about twenty years ago lead piping was universal. The introduction of light-gauge copper piping has made copper piping a formidable rival to lead piping, although lead pipes are always used from the main pipe underground to the house. In older houses water was first delivered into a cistern and from this distributed to the fittings. Modern houses are supplied in many cases direct from the main except for the hot-water systems which have a small feed cistern of about ten gallons.

Water for Fire Extinguishing Purposes. Generally it may be said that the main pipes in most towns are not adequate, except in the main streets, to supply water for fire-extinguishing purposes. Fire brigades exist in all large towns, but in the smaller places these depend

on local volunteer fire brigades. Fortunately large fires are not too common, although millions of pounds damage are done yearly by fire: the interest on the losses would provide very efficient fire brigades in the country. There has now been passed a Fire Brigades Act which, when its provisions have passed, will put an end to the unsatisfactory conditions relating to fire protection; but no fire brigade can operate without an adequate supply of water, and for this reason it will be necessary for most water authorities to lay much larger pipes if these are to be used for fire extinguishing as well as for domestic and industrial purposes.

Air Raid Precautions. The British people are slow and dilatory in things they consider are not of vital importance. It has been gradually forced upon us, however, that not only must we be prepared to meet possible aggression on the Continent of Europe but also attacks on our own cities from the air. Those who would have others believe that we are an effete and decaying nation would be considerably surprised if they knew how much is being done in the way of meeting possible emergencies. But only that which is applicable to water authorities can be dealt with here. Let me therefore conclude this paper with a brief account of what the Water Department of Edinburgh has done in this connection. Every man of the Department has been trained in anti-gas and to work in anti-gas clothing, and every man has an allocated duty in emergency. Depots have been established at various points, and air raid shelters have been constructed. Each depot will control and deal with repairs in a special area. Duplicate mains are being laid, and many additional valves are being placed on trunk and distribution mains so that in emergency the water can be shut off in short sections which are damaged by bombs, while the rest of the supply is maintained. We are spending $125,000 on additional valves and new piping purely for air-raid protection. Everything is being done to maintain, as far as possible, a continuous supply of water to the half million inhabitants of Edinburgh in times of aerial bombardment. The Government subsidises approved expenditure to the limit of 50 per cent. While we hope that such emergencies will never arise we are prepared to meet such emergencies should they come. This single example is but one of the whole scheme for water supplies throughout the country.

In conclusion let me thank you for the privilege of preparing this paper.

Discussion

Caleb Mills Saville.* It afforded me much pleasure to receive the request from the Chairman of your Program Committee to take part in the dicussion of Mr. Bowman's paper. The New England Water Works Association is to be felicitated in being favored with this résumé of British practice, not only because the information therein is most welcome and helpful to waterworks men in America, but also because of its preparation by a well-known British water engineer, who at this time has been honored at home with the Presidency of that Society which parallels our own here in New England.

In his foreword, Mr. Bowman expresses the hope that the information contained in his paper will form "a basis of comparison between practice in New England and in Great Britain." The following discussion is an attempt to bring before you some conditions here that it is hoped will be of help in carrying out Mr. Bowman's desire.

Geographically, Great Britain and New England, over three thousand miles apart, are not so situated on the surface of the globe as to bring expectancy of some of the similarities that exist, a reason for which, however, Mr. Bowman calls to attention in his paper.

To bring these matters more vividly to your mind, a few facts are stated which some of us may have forgotten and for which it was necessary to consult the atlas for geographical position. In point of latitude, London (Eng.) is 51°-30′-48″ north, and Boston, 42°-21′-27″ north; that is, London is 9°-9′-21″, or 631 miles further north than Boston.

Roughly speaking, Edinborough is about as far north of London (306 miles) as London is north of Quebec (325 miles) as Quebec is north of Boston (306) miles). The most southerly point of England is Lat. 50° North, or some 527 miles north of Boston, or about as far north as Newfoundland and the Gulf of St. Lawrence.

In some respects the topographical features of England resemble those of New England with ranges of mountains on the west parallel with the ocean and with land sloping gently to the southeast. Mr. Bowman gives the area of Great Britain as 121,000 sq. miles which is a little less than double that of the six New England states (66,424 sq. miles), or about 5,000 sq. miles larger than the combined area of New England (66,424) and New York State (49,204).

For comparison with English and Scottish rainfall, the normal

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annual rainfall* of the northern section of New England is 38.81 in., and for the southern section, 44.26 in. The annual normal (50 year) rainfall is variable over the entire section, ranging from 32.88 in. at Northfield, Vermont (interior), to 41.95 and 45.92 in. at Portland, Maine and New Haven, Conn., respectively, located on the ocean shore-line in the northern and southern sections of New England.

TABLE 3—NORMAL MONTHLY RAINFALL IN INCHES FOR YEARS OF RECORD ENDED 1930
(Climatic Summary of the United States, Sections 84, 85, 86).

	STATIONS						
	INTERIOR			COASTAL			
	NORTHFIELD	SPRINGFIELD	CONCORD	PORTLAND	NEW HAVEN	BOSTON	HARTFORD
Jan.	2.19	3.28	2.67	3.86	3.90	3.62	3.43
Feb.	2.18	3.49	2.48	3.67	3.96	3.44	3.47
Mar.	2.61	3.58	2.95	3.87	4.18	3.91	3.79
Apr.	2.28	3.20	2.93	3.39	3.76	3.76	3.34
May	2.69	3.73	2.95	3.42	3.72	3.51	3.54
Jun.	3.28	3.64	3.13	3.65	3.14	3.13	3.20
Jul.	3.44	4.31	3.53	3.35	4.35	3.57	4.03
Aug.	3.47	4.27	3.18	3.42	4.46	3.96	4.24
Sep.	2.97	3.42	2.99	3.09	3.40	3.30	3.37
Oct.	2.72	3.79	3.00	3.33	3.67	3.48	3.61
Nov.	2.78	3.57	3.38	3.52	3.57	3.93	3.66
Dec.	2.27	3.34	2.61	3.78	3.81	3.69	3.41
Annual	32.88	43.62	35.80	41.95	45.92	43.30	43.09

At individual stations, however, the rainfall throughout the year is comparatively uniform. A rainday in British meteorological parlance, is a day in which 0.01 in. or more of rain is recorded. The average number of raindays in New England is 128†, or about 37% less than that of England, varied from 112 at Springfield, Mass., to 152 at Northfield, Vermont, both interior cities. For the coast cities, the average of 131 seems representative.

For wet days, that is, days with 0.04 in. of rain or more, the 16-year record (1923-1938) gives an average of 96 for the three southern New England states which is about 18.5 less than the number of raindays (120) for the same group.

For extremes of monthly precipitation, there is a maximum of 8.84 in. for Boston (January) and 17.08 in. for New Haven (July),

*U. S. Weather Bureau 1939.
†Years of record at seven stations varying from 28 years to 66 years.

with minima of 0.35 in. for Boston (Jan.) and 0.54 in. for Hartford (July). The following are given as extremes of annual precipitation in this section:

	ANNUAL PRECIPITATION IN INCHES FOR YEARS OF RECORD	
CITY	MAXIMUM	MINIMUM
New Haven, Conn.	60.96 (1920)	33.06 (1930)
Hartford, Conn.	60.26 (1888)	33.89 (1819)
Concord, N. H.	59.69 (1920)	30.74 (1908)
Portland, Me.	54.31 (1863)	26.10 (1930)
Northfield, Vt.	45.89 (1888)	27.36 (1899)

Recent isohyetal maps of annual rainfall variability indicate for the New England states that the range for this section of the United States during the years of record has varied from a minimum of about 30 in. per year to a maximum of about 60 in., and an average of about 45 in.

For Central Connecticut (West Hartford Station, Water Bureau, Metropolitan District) during the years of record (1868 to 1938 inc.) the annual rainfall has been:

PER CENT. OF TIME	INCHES OF RAINFALL
100	28.90 or more (min.)
75	38.95 or more (min.)
50	43.40 or more (min.)
25	48.36 or more (min.)
0	56.95 or more (max.)

For evaporation, that of southern New England is nearly three times (39.2 in., FitzGerald) that of Great Britain.

For temperature in New England, the U. S. Weather Bureau normals are:

	TEMPERATURE—°F.		
CITY	ANNUAL	JANUARY	JULY
Hartford, Conn.	50.1	28.8	72.2
New Haven, Conn.	50.0	28.5	72.9
Portland, Me.	45.8	21.2	69.7
Concord, N. H.	45.4	22.4	68.0
Northfield, Vt.	41.3	15.4	65.6

For Great Britain, the variations are indicated on the climatic (isometric) maps of the British Isles (Fig. 2) presented in Mr. Bowman's paper following his discussion of climatic conditions. As isometric methods of expressing meteorological conditions are not used in this country to the extent as in the British Isles, for purposes of

comparison with New England records, the following station averages (annual) for Great Britain are taken from the Monthly Weather Report of the Meteorological Office (British) Summary:

	TEMPERATURE—°F.		
CITY	ANNUAL	JANUARY	JULY
Edinborough	46.9	39.1	57.7
London	51.2	40.3	64.3
Southampton	50.0	40.9	62.9
Manchester	49.3	40.7	60.9

As to early public water supplies: The first public water works in the United States was at Bethlehem, Pa., in 1762.* The first steam pumping plant for water service was at Philadelphia in 1797. Water was obtained from Lake Cochituate for the City of Boston in 1848 and for many years prior to that, parts of Boston had been served by private enterprise from Jamaica Pond and other sources as early as 1652.

As in England, most of the large towns and cities are now supplied from municipally-owned works, only two or three large cities in New England being still under private control for water supply.

For sources of water supply: In Massachusetts, out of 282 reporting, 140 are from ground water and 142 from surface sources. In Connecticut, of 116 reporting, 67 are from surface supplies, 39 from ground water, and 10 combined surface and ground. As stated by Mr. Bowman, however, these figures are misleading as in both Massachusetts and Connecticut, the large majority of water consumers are supplied from surface water sources.

In 25 of the larger cities of the country, for storage provided in impounding reservoirs,† the average amount was 316 days' supply, and of these, seven only were under 100 days.

The Vyrnwy Dam which Mr. Bowman cites as the first masonry dam of magnitude to be constructed in England, was built between 1881 and 1892 by that very eminent English waterworks engineer, Dr. G. F. Deacon. At about that time, the beginning of the 1890 decade, masonry dams of magnitude also were being constructed in this country; for example, the Sodom Dam of the New York City Water Supply (1888-1893) and several others. The Bear Valley masonry dam in the Bernardo Mountains, California, was constructed in 1884. This dam was 64 ft. high, of very thin section and dependent upon its arched form for stability.

*J. T. Fanning, "Public Water Supply."
†Report on Future Sources of Water Supply for City of Baltimore, 1934, p. 80.

As of December, 1894, Mr. Frederick P. Stearns, an honored member of this Association and one of the most distinguished hydraulic engineers of this country, after several years of study, presented the plans for the construction of the Wachusett Dam on the South Branch of the Nashua River. This dam provided the large storage reservoir at Clinton, Mass., for the water supply of the Boston Metropolitan District. At its completion, it ranked among the great masonry dams of the world, 1250 ft. at flow line length and a maximum depth of 158 ft. from high-water level to rock on the downstream toe. In the ten years prior to this, several large masonry dams had been planned or constructed for the New York City water supply, the most important being the Quaker Bridge Dam on the Croton River, which was an epoch-making proposition.

In the matter of circular or bellmouth spillways, that designed and built at the Harriman Reservoir† in southern Vermont was among the first in this country. The latest of this type spillway designed with all the refinements of modern model practice is that at the "Gorge" dam at Hong Kong, now being built under the direction of the internationally known English firm of engineers, Messrs. Binnie, Deacon and Gourley of London, England.

In the matter of compensation for water diverted from industrially developed streams, American practice varies from that of England in that the law here requires money compensation unless compensation in kind can be arrived at by negotiation. In British practice, an act of Parliament, as stated, determines the amount of water to be let down the stream. There are some points in favor of both methods, and either method as well may lead to disproportionate results.

The New England States, as a rule, have very limited areas where water can be obtained from underground sources in large quantities, but many smaller water supply systems are adequately served from such sources. The underground water resources of Long Island, just across the Sound of the same name, from Connecticut, afford an immense supply from the beds of unconsolidated glacial drift. There are practically no surface streams on this island which has an area of about 1400 sq. miles, and as much as an average of 135 m.g.d. for long periods, not including that drawn for private industry, has been drawn for public water supply from about one-third of the western part of the island. The quantities withdrawn in the past, how-

†Trans. Am. Soc. C. E., Vol. 88, 1925.

ever, have so depleted the underground storage that in many localities the salt water from the ocean is seeping in, to the ruin of the wells.

A similar supply is obtained for the water supply of the locality about Atlantic City, N. J., and similar conditions of exhaustion are being noted.

The eastern part of this country has no beds of chalk deposit similar to the extensive beds underlying London and other localities in eastern England, from which large quantities of excellent water are being daily drawn for public use.

As to the purification of water, the method of slow sand filtration developed in England was first established in this country at Poughkeepsie in 1872 by Mr. J. P. Kirkwood. These were known as the "English" type filters, and they had considerable vogue here for 20 years, and are now the best type under certain conditions. They are particularly adapted to New England waters. By all odds they are the safest and most economical in practice where they can be used to advantage. The area required and the first cost of the plant, however, so militate against them that the "American" rapid type of filter, using chemicals under expert supervision, has practically superseded them in America and is rapidly taking their place abroad.

The largest rapid sand plant in this country is that at Baltimore, Md., with a capacity of 240 m.g.d. The largest slow sand filter plant is that at Philadelphia, Pa., with a capacity of 80 m.g.d. For works depending on natural conditions only, and without filtration, the supply of the Boston Metropolitan District, now supplying about 140 m.g.d., is the largest in New England. This supply, however, is chlorinated, and the watershed under strict sanitary supervision as well as the advantage of long storage.

The best sanitary thought in this country is that no natural water supply for human use, if unfiltered, is safe, except as it is sterilized, and the same precaution applies to the effluent of all rapid sand filters.

As to the amount of water for public use, the consumption of water per capita in the industrial cities of New England seems to keep pace with that of England; Lowell, 54; Lawrence, 49; New Bedford, 78; Somerville, 91 and Boston, 105. All of these supplies are in Massachusetts and are fully metered. For fully metered residential communities, there are Brookline, 55 gal. per capita; Newton, 69, and Winchester, 65. The difference between England and New England consumption seems to be not in the use of water by the population, but by its use in industry, comparatively little of the total amount being generally used in domestic service abroad.

As the installation of modern home appliances makes greater way in England, undoubtedly the amount of water per capita will show considerable increase due to household uses, and it would seem probable that within a few decades, some parts of England might be put to it for adequate supply. This statement seems to be borne out by the 46 gal. per capita in Glasgow with no industrial use which compares with similar use in this country. As to "housing" schemes and the introduction of modern plumbing in the cheaper class of homes, something other than plumbing is necessary where present bathtubs are used casually for baby parking or coal pockets, the toilets for garbage disposal and the fire escape landings of apartment houses for storage of rubbish containers.

In the matter of "Standardization of Water Fittings," Great Britain is far ahead of the United States, and it is time that some steps were taken in this matter here to insure proper plumbing fixtures and fittings.

For pipes and pipe lines, American practice seems to follow substantially that in Great Britain. For service pipes, lead practically has been abandoned in most New England systems when the water is sufficiently soft to cause trouble. Copper tubing has taken its place to a considerable extent, but that material too also is susceptible to attack from certain waters. By and large, the old-fashioned genuine wrought-iron pipe, cement-lined, has stood the test the best of all and seems the only pipe in which dependence can be placed.

We are thankful that up to the present it has been unnecessary for us to consider air-raid precautions, but coöperation against disruption of service from floods has been a real problem and in many cases has worked out in a satisfactory manner, to the advantage of several neighboring communities. More of this kind of precaution should be attempted.

The paper of Mr. Bowman and the observations made in this discussion show plainly how strictly analogous British and New England waterworks practice has become. This, of course, might be expected from peoples whose roots are in the same soil and whose general policies follow similar tracks.

Again let me express my appreciation of the very interesting and instructive paper that Mr. Bowman has been so good as to give to us, and it is to be hoped that the exchange of papers between our two water supply organizations may continue for our mutual advantage.

May I also express the wish, which I know will be echoed by every

member of the Association, that the Edinborough Water Supply System and all others in Great Britain, may escape damage during this unhappy period, but that if called to service, the precautions taken may be most effective.

ROBERT SPURR WESTON.* With the wealth of facts which Great Britain possesses and the abundance of interesting details in connection with the development of the art of water supply within its borders, it is remarkable that Mr. Bowman has been able to give his hearers so comprehensive a view of water works practice in so brief a paper.

Beginning with the fundamentals of geography, topography, rainfall and runoff, he prepares us well for the technical description of conditions and works which follows.

As in America, climatic conditions vary widely, and while variations in annual rainfall even wider than those in Great Britain exist in the United States, it is surprising that so wide variations occur within an area of only 121,000 sq. miles. Furthermore, it is remarkable that with these wide variations there should be so few heavy showers and a rate of evaporation about one-third of that observed in New England.

The account of development of works, first by companies and later by municipalities and districts, is in line with American experience. On the other hand, the predominance of upland surface supplies even for small towns is contrary to practice in American communities where many ground water supplies exist.

Very interesting is the account of compensation water practice. To compensate downstream owners with more than one-half, or even one-third, of the yield of a reservoir would be unthinkable in North America, and the practice evidently calls for revision in Great Britain. Compensation in kind rather than money would seem to evidence the social and political influence of early riparian owners. Evidently the rights to underground water need clarification also, as they certainly do elsewhere.

The quality of British waters has always been high, and the citing, fifty years ago, of Loch Katrine water by the writer's professor of chemistry as an example of high quality is well remembered.

As elsewhere, British health authorities are adding new lines of sanitary defense, even to ground waters. This is more easily accomplished where consumption is low, as in Great Britain, than where great waste occurs as in one New England city where the consumption

*Of Weston & Sampson, Consulting Engineers, Boston, Mass.

is over 300 gal. per capita. However, increased consumption in England will certainly follow the recent improvements in housing conditions and the more general introduction of baths and water closets.

It is sad to realize that protection against aerial bombardment is such a factor in water works practice in Great Britain, and it is hoped that the time will come when the author and his colleagues may devote their entire energies toward the convenience and health of water consumers and not be affected by the horrible strife of the present day.

T. H. WIGGIN.* I have read with interest Mr. Bowman's very clear and illuminating word-picture of British water supply conditions and practice. This is the more concrete to me since I was fortunate enough a few years ago to spend two months in England and Scotland and during this visit saw something of their water supplies.

The first noticeable fact is the lower than expected rainfall except in certain places. It is generally not more than that on the Atlantic coast of the United States. One gets a false impression of the total rainfall of Great Britain from its well known frequency. Smaller impounding reservoirs would obviously serve to produce a given safe yield. It would be interesting to see a mass diagram of run-off for a series of relatively dry years in Great Britain in comparison with similar diagrams for the Sudbury River for example.

British water works practice is not fundamentally different from that of New England. In spite of the large population relative to area there is a surprising lot of largely unoccupied land in England and Scotland so that beautiful surface water collecting areas exist. The source of the Glasgow supply, Loch Katrine, is beautiful beyond description and the country is so sparsely occupied as to give the impression of highest purity, which in truth exists as proved by the absence of waterborne disease in Glasgow without benefit of filtration or chlorination. The Upper Thames, source of much of London's supply, while less wild, is still far from crowded and gives one a feeling of pleasure in its cleanliness. In fact, I have the impression that the British treat their country more kindly than do we Americans and, while the enjoyment of bicycling and tramping by the less well-to-do is more general than in this country, I do not recall seeing signs of picnicking or unsightly dumping.

Mr. Bowman has mentioned the need for larger distribution mains if real fire protection is to be attained. I was impressed by the small size of mains, 3, 4 and 5 in. in diameter in city streets and the

*Consulting Engineer, New York, N. Y.

small hydrant connections about 2 in. in diameter, coming straight up from the mains to a box in the street. Much of the water of England and Scotland is incredibly soft, even softer than that of New England, and tuberculation of pipes is very copious, often nearly filling the bore of the small pipes and graphitizing the metal to a greater extent than I have seen anywhere in America. This adds to the difficulty of domestic and fire supply. In Manchester the Tate process of lining pipes in place was being used extensively to recondition 3-, 4- and 5-in. distribution pipes. In Birmingham, I was informed, the Eric system of electric deposition of asphalt from emulsion was being used. Incidentally, the exterior corrosion was heavy. In Manchester and other industrial cities, cinders, which for a long time have been the customary material used in the grading of streets, seemed to be the recognized cause of this corrosion, but no attempt was being made to keep the cinders away from the pipe when refilling.

At Manchester, pipes and fittings were tested by hydraulic pressure in the City's pipe yards, and I understood that this practice was common.

I saw one new mechanical filter of a modern masonry type on the Upper Thames but did not hear of many of this type. I got the impression that the development as regards treatment of water has been not dissimilar to that of New England where for a long period during the regime of the late Frederic P. Stearns and X. H. Goodnough, generous storage with a minimum of chlorination and filtration were the rule; subsequent to which chlorination has become general, I believe, and rapid sand filters common. It is natural that the development in Great Britain should be similar, since the upland waters of the British Isles, like those of New England and other similar parts of the Atlantic states further south, are generally clear and soft so that filtration is not usually a necessity so far as clarity is concerned.

I did not hear reference made to the complications and refinements of coagulation, floculation, pre and after chlorination, treatment with carbon, lime, silicate of soda, metaphosphates, etc., which are so much in evidence in America. Probably these methods are also in use in some places in Great Britain, but discussions and propaganda are not so common.

I got the impression that the British take their engineering more simply than we do, and this confirms the impression which I gained in a two-year residence in China from 1919 to 1921, where I worked near another governmental engineering agency headed by a prom-

inent British engineer. I recall his comments on some comparative cost estimates which I had made of two ways of doing some canal work. He asked "Do you Americans always estimate the cost of various ways of doing a job?" On my answering in the affirmative, he said "We don't. We try to find the best way of doing a job and then do it that way." I have generally found that various good ways of doing a work cost about the same; so there may be justification for the point of view expressed by the British engineer.

By reference to my notes I find that I had a conversation with Mr. Bowman in his office in Edinburgh on September 24, 1934 and through his courtesy and that of Mr. Reed, one of the consulting engineers on the Edinburgh water supply, was enabled to inspect some very old cast-iron pipe in a tunnel leading from the lower ground up to the Castle and an adjacent reservoir. The 15-in. pipe in this tunnel was still in good condition exteriorly at least. It had cast on each length the initials E.J.S.W.Co. B. & Co. 1821, the first group of letters I was told standing for Edinborough Joint Stock Water Co. and the last group of characters standing for the makers and date of casting. Some 5- and 7-in. pipes in a branch tunnel I was told were much older. They supplied the Castle.

In recent years I have heard considerable about a "water mine" installed to extract ground water from a stratum beneath the Thames river. This consists essentially of a shaft with horizontal wells driven out in star formation.

E. J. CLEARY.* Some years ago I talked with the engineer who installed the Ranny radial well system for the Metropolitan Water District in London, which was mentioned by Mr. Wiggin. The scheme works in this fashion: A vertical shaft is sunk, and pipes of varying length are extended horizontally and radially from the shaft. These pipes are projected into water-bearing strata encountered at various levels in the shaft; the pipes are perforated with holes and thus serve to drain water from pervious areas into the central shaft.

This installation, I was told, received the interested attention of the Ministry of War because of their concern with protection of water supply facilities during air raids. One advantage cited for the radial well collector was that the installation is entirely below ground and nothing appears on the surface but a trap door opening for access to the pumps and valves in the shaft. It was stated, also, that

*Associate Editor, Engineering News-Record, New York, N. Y.

during periods of high flow in the Thames, water could be diverted into the shaft as a means of recharging the pervious underground strata.

In this country a radial well collector similar to the London system was installed in 1937 by the Timken Roller Bearing Co. at Canton, Ohio. Another installation is reported to be underway for the municipal water supply of Binghamton, N. Y.

E. SHERMAN CHASE.* A few years ago I also had the opportunity to see something of English water works systems, and there are a few impressions that I still carry with me. The first is in connection with English data relating to yield of watersheds. Much to my surprise, in visiting Mr. Gourley's office, I saw on his book shelves numerous volumes of United States Geological Survey Water Supply Papers. When I expressed my surprise, he said, "Oh, yes, the runoff records for the New England areas are of real help to us, with proper interpretation, due to the fact that, although we have very long records of rainfall, we have very little in the way of gauged stream flows." Talking later with other British engineers, I found great complaint about the failure of the government to have carried on anywhere near the stream-gauging program that our Geological Survey has been undertaking for so many years.

Another point of interest that came to my attention in looking over the London water supply was in connection with its long storage, which most of us New Englanders have been led to believe is nearly the best thing in water treatment next to slow sand filters. In talking with the Deputy Chief Engineer of the Metropolitan Water Board he said, "We do have long storage, but in my opinion it is a bit too long, because with the Thames River water stored for a long period of time we get growths of micro-organisms, which bring about an impairment in quality that is difficult to remove by our filtration processes." Incidentally, in connection with those London supplies, some of them, at least, are being subjected to double filtration,—rapid filtration preceding slow sand filtration, but without the use of chemicals.

Another practice in England, in connection with water purification, that seems to prevail more than it does in this country at the present time is the comparatively generous use of pressure rapid sand filters on municipal supplies. It is very seldom in this country that

*(Of Metcalf and Eddy, Consulting Engineers, Boston, Mass.)

pressure mechanical filters are used on municipal supplies, although they are used for industrial purposes. In connection with filtration, it is more or less English practice for the water works engineer, in laying out a system and in making his drawings, to leave a space where the water purification plant is to be located and then to receive bids, or tenders, as they say, from filter-plant manufacturers, for the design as well as the installation of a filter plant.

In connection with the matter of small mains and small available fire supplies, as compared with what we think are required, it may be due in part to the fact that frame buildings of wood construction are relatively few in the British Isles. That may be one reason why they get by without appalling fire losses.

WILLIAM W. BRUSH.* There is one point about English water supply practice from the viewpoint of fittings in houses that has not been mentioned, and that seems to me to have a very definite bearing on the relatively low consumption: the compulsory limitation of the size of flush tanks for toilets. As I recall, 2½ gals. is the standard flush-tank capacity, whereas here we normally have a flush of from 5 to 8 gals. When one considers the percentage of domestic demand that is represented in the toilet flush, it can readily be seen that the small tank capacity has a decided influence on the water demand.

I was also impressed by the way London, and, as I understand, some of the other cities, look after the waste from the underground piping system. In London, the number of men employed on underground waste control is very much larger than is usual for similar size systems in this country, and those men go after leaks that are of such small size that the usual American water department would consider it was not economical to attempt to locate and stop them. Leak-detection work in London is carried on largely during the nighttime. I was told by Colonel Davidson, Chief Engineer of the London supply, that one-half his distribution storage was inside the buildings of consumers, the other half being in the form of storage reservoirs connected with the London system. Therefore, services can be shut off at the curb for several hours while the flow into one or more sections is being measured. Unaccounted flow is considered leakage and carefully searched for with aquaphones.

I was also rather surprised by a number of cities with populations up to 50,000 or more having water supplies posted as being

*Editor, Water Works Engineering, New York, N. Y.

unsafe for domestic consumption, but the posting was in the form of very small signs that one would find above the basin.

It is rather remarkable, when one considers the way in which water is used in the New England cities, that so many of them have per capita consumption demands that are very close to the English and Scottish figures. Mr. Bowman told me in 1934 that he expected to see the demand for water in Great Britain increase and ultimately come well up to our American values. While the 2½ gal. flush is an illustration of attempted water conservation, my observations indicated that under certain conditions one had to flush the toilet two or three times, so that at times the total amount of water used would be about the same as over here.

KARL R. KENNISON.* Although we are accustomed to think of old England as being very much older than New England it is interesting to note that the two have, more or less, kept pace with each other in the development of large public supplies.

I note that what Mr. Bowman calls the merged public administration of the supply in London was started about forty years ago, at about the time the Metropolitan Water District was organized in the Boston area. Also, although, as Mr. Bowman and Mr. Saville noted, some public supplies of much greater age can be noted in both old and New England, the development of what Mr. Bowman calls proper, systematic water supplies is just about 100 years old in each.

A fundamental difference, as I see it, is due to the uniformity in England of meteorological conditions, well summarized by Mr. Bowman's figure of an intensity of 1 inch per hour of rainfall occurring only once in ten years. This and the fact that the evaporation in England is only about a third of ours accounts for the smaller storage capacities required.

It might also be emphasized that the use of storage is considerably affected by the peculiar porous character of the underlying rock in England, which permits a much greater use of ground water. Ground water is used for London itself, as I understand it, to a much greater extent than one would infer from the information that Mr. Bowman gives.

One interesting statement of his was that in England the legislature determines the compensation for property taken. While that fact has not been noted by any of the discussers, I believe that would be unconstitutional in this country. We provide for compensation but

*Chief Engineer, Metropolitan District Water Supply Commission, Boston, Mass.

our compensation cannot be determined by law. The rights of the individual are so jealously guarded in this country, even as against the state, that the individual has the right to seek greater compensation by a jury trial. I understand that this is not true in England, but that the determination rests with the legislative body.

As to the relative amount of compensation water, we have in our Metropolitan District in Boston two extreme cases that are interesting for comparison. In the case of water being let down to provide all manufacturing plants and power plants with an ample supply, the amount let down was fixed with an idea of discouraging or eliminating damage suits, and that amount was between eight and nine tenths of the average flow. The intention was to take what might be called flood flows. In another special case there was only one industry below the point of diversion, and the intention there was to let down the very minimum quantity that the industry could get along with. The amount let down was about one-tenth of the average flow.

FRANCIS H. KINGSBURY.* There occur to me other instances of the legislative control of the amount of water reserved for industry with which Mr. Kennison is no doubt familiar. The legislation that permitted the city of Boston to develop a water supply on the Sudbury River required that 1,500,000 g.p.d. be permitted to flow in this stream below the lowest dam on the water works system. The subsequent legislation that authorized the Metropolitan Water District to construct a dam on the South Branch of the Nashua River at Clinton recognized the needs of the Lancaster Mills, which were located directly below the dam, and required that not less than 12,000,000 gal. per week be permitted to discharge into the stream at the dam for the use of these mills and such further quantity not exceeding 12,000,000 gal. per week as the owners of such mills should from time to time certify to be necessary. The legislation permitting Salem and Beverly to take water from the Ipswich River during the months of December to May, inclusive, contained the provision that no water should be taken when the flow was less than 20 m.g.d. at the point of taking and the legislation permitting the cities of Lynn and Peabody to take water from the Ipswich River at a point upstream contained a similar provision based on the ratio of the drainage areas and that no water should be taken when the flow was less than 10 m.g.d. When the West Mansfield supply of the city of Attleboro

*Massachusetts State Department of Public Health, Boston, Mass.

was developed for the taking of water from the ground near the Wading River, the dam was raised to provide compensating water for the downstream mill owners. On the Ipswich River and in connection with the West Mansfield supply of the city of Attleboro, the Legislature delegated certain regulatory powers to the Department of Public Health. In the case of the Ipswich River the legislation delegated to the Department of Public Health the power to permit the taking of water above the limit set therein during the months of June to November, and in the case of recent Attleboro legislation the Department of Public Health was given the power to determine when and in what quantities water should be discharged from the compensating reservoir.

CONSTRUCTION AND OPERATION OF RAPID SAND FILTERS AT LAWRENCE, MASS.

By ARTHUR L. SHAW* and E. SHERMAN CHASE*

[*Read September 14, 1939*]

The installation in 1893 of the original slow sand filter at Lawrence, Mass., for the purification of the supply taken from the grossly polluted Merrimac River, constitutes a landmark in the history of water supply sanitation. This filter, although not the first to be constructed in the United States, was the first to be designed on the basis of scientific principles established by the researches of the Lawrence Experiment Station of the Massachusetts Board of Health. It is of particular interest to the members of the New England Water Works Association that this filter was built after the designs of the late Hiram F. Mills, Honorary Member of the Association. It is also of interest to point out that the late Allen Hazen, Past President of the Association, carried out the pioneer experiments on filter sands, which played such an important part in the design of the first Lawrence filter and other filters in all parts of the country.

The immediate reduction in the typhoid fever death rate of Lawrence demonstrated the value of filtration. As time went on, more filters were added and other improvements made. The original open filter was divided into three sections in 1902, and in 1917 the easterly section was covered. New covered filters were added in 1907 and 1925, after the designs of the late Morris Knowles, for many years a member of this Association. Chlorination was begun in 1918.

The effect of improvements in the water supply of Lawrence upon the typhoid death rate of the city are clearly shown in Figure 1 and Table 1. The typhoid rates of the state of Massachusetts and of the city of Boston are also given for comparison.

Although slow sand filtration and chlorination produced a relatively, but not uniformly, safe supply, the physical characteristics of the treated water were not fully satisfactory. The popular discontent with the color and taste of the water, together with recommendations for an improved supply made by the State Department of Public Health, eventually led to the construction of modern rapid sand filters to be used in conjunction with the existing covered slow

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TABLE 1.—TYPHOID FEVER DEATH RATES IN LAWRENCE, BOSTON AND MASSACHUSETTS

YEAR	DEATH RATES PER 100,000 POPULATION			YEAR	DEATH RATES PER 100,000 POPULATION		
	LAWRENCE	BOSTON	MASSACHUSETTS		LAWRENCE	BOSTON	MASSACHUSETTS
1879	60	33.2	36.2	1909	21.6	13.8	11.8
1880	69	42.4	49.4	1910	16.2	11.3	12.2
1881	125	56.2	59.1	1911	11.5	8.8	8.8
1882	79	56.7	58.4	1912	13.6	8.1	7.7
1883	72	52.2	45.9	1913	13.5	8.4	7.8
1884	49	56.1	45.9	1914	8.9	9.3	7.4
1885	44	38.9	39.4	1915	8.8	5.4	6.6
1886	57	33.6	40.0	1916	8.8	3.5	4.6
1887	114	44.3	44.9	1917[4]	6.5	2.9	4.7
1888	114	40.1	44.6	1918[5]	10.8	2.5	4.2
1889	126	42.6	41.0	1919[5]	8.5	2.2	2.8
1890	134	34.6	37.4	1920	8.5	1.5	2.4
1891	119	33.6	35.4	1921	4.3	3.1	3.0
1892	105	29.3	35.4	1922	1.0	1.4	2.2
1893[1]	79	31.0	31.4	1923	4.3	1.0	1.7
1894	49	29.0	30.6	1924	3.2	2.1	1.7
1895	35	32.5	27.2	1925[6]	1.1	3.5	1.8
1896	26	31.4	28.3	1926	1.1	1.8	1.5
1897	25	32.7	23.2	1927	1.1	1.1	1.0
1898	24	34.0	24.8	1928	2.3	0.6	0.85
1899	35	29.7	22.3	1929	2.3	1.6	0.99
1900	21	25.5	22.5	1930	0.0	0.8	0.89
1901	20	25.0	19.7	1931	1.2	0.9	0.70
1902[2]	23	24.2	18.6	1932	2.5	0.5	0.58
1903	34	20.5	18.0	1933	0.0	0.2	0.50
1904	16	22.9	15.6	1934	0.0	0.9	0.29
1905	21	19.6	17.3	1935	0.0	0.5	0.2
1906	19	20.3	15.4	1936	0.0	0.1	0.2
1907[3]	30	10.3	12.3	1937	0.0	0.0	0.3
1908	24.9	25.0	16.0	1938	1.1	0.2	0.2[7]

Statistical data for Lawrence and Massachusetts from Massachusetts Department of Public Health; data for Boston for years 1879 to 1906 from Whipple's "Typhoid Fever," for 1907 to 1909 and 1937 and 1938 from Massachusetts Department of Public Health; for 1910 to 1915 from U. S. Census reports; for 1916 to 1936 from Journal, American Medical Association.

[1]First Lawrence filter started on September 20, 1893.

[2]Lawrence filter divided into 3 sections in 1902.

[3]West covered filter built at Lawrence in 1907.

[4]Old east filter unit at Lawrence covered in 1917.

[5]Chlorination, with hypochlorite, of Lawrence filter effluent begun in December 1918, and with chlorine on May 21, 1919.

[6]North covered filter built at Lawrence in 1925.

[7]Rapid sand filters started at Lawrence on December 16, 1938.

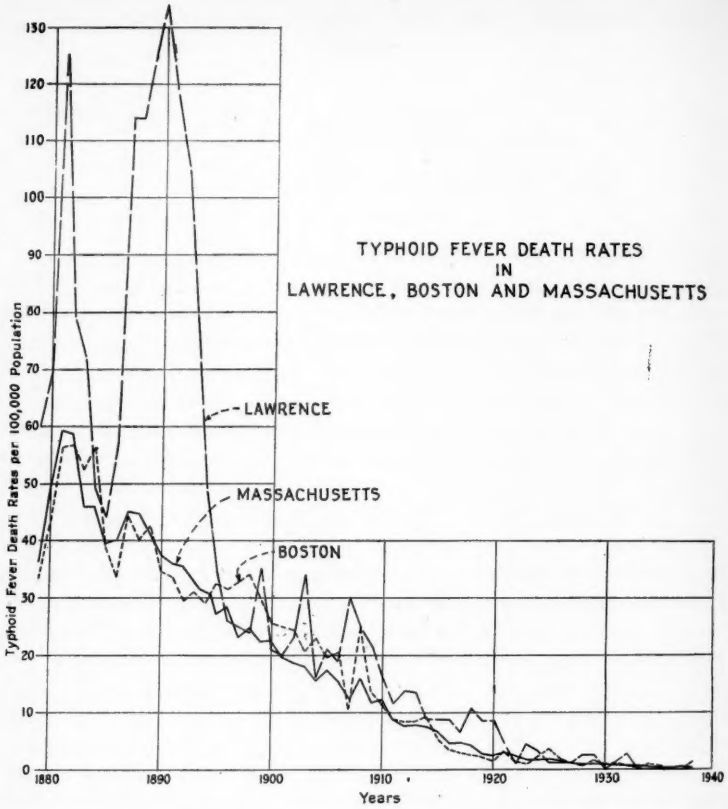

FIG. 1.—TYPHOID DEATH RATES IN LAWRENCE, BOSTON AND MASSACHSUETTS.

sand filters. The actual undertaking of this work in 1937 was stimulated by the grants-in-aid program of the Federal Government, under the Public Works Administration, whereby approximately 36% of the cost of the project was borne by that agency.

Source of Supply. The Merrimac River above the filter plant has a drainage area of approximately 4461 sq. mi., exclusive of areas diverted for water supply purposes on the Nashua River. The average discharge of the river as estimated from gagings at Lawrence between October 1879 and September 1934, is 6661 sec.-ft. At the time of the 1936 flood a maximum flow of 173,000 sec.-ft. occurred

at Lowell on March 20th. This flood inundated the Lawrence filters and pumping station.

Direct discharge of untreated sewage into the river and its tributaries occurs at Concord, Manchester and Nashua in New Hampshire, at Lowell in Massachusetts, and at numerous smaller municipalities in both states. The city of Lowell, with its sewage and industrial-waste discharges, is located some 9 miles, only, upstream from the Lawrence intake.

Information regarding the industrial wastes reaching the river is meager. Among the industries contributing wastes are paper mills, tanneries, gas works, woolen mills and other textile mills. Morris Knowles, Inc., in a report made in 1917 upon the Lawrence water supply problem, estimated that 63 m.g. of wastes were discharged into the river above Lawrence from 116 plants each working day, and that the quantity of solids discharged in the wastes amounted to one million pounds per day. It is probably true that in 1917 there was abnormal industrial activity due to the war, but the figure cited gives some conception of the very large industrial-waste burden placed upon the river.

Table 2 shows the populations of the principal cities and their distances above Lawrence, together with estimates of the volumes of

TABLE 2.—PRINCIPAL CITIES AND TOWNS ON MERRIMAC AND NASHUA RIVERS. POPULATIONS, DISTANCES ABOVE LAWRENCE, AND ESTIMATED VOLUMES OF SEWAGE DISCHARGED TO RIVERS.

CITY OR TOWN	POPULATION (1930 CENSUS)	DISTANCE ALONG RIVER, MILES	ESTIMATED VOLUME OF SEWAGE,[1] M.G.D.
Merrimac River			
Lowell	100,234	9	7.5
Nashua	31,463	23	2.4
Manchester	76,834	41	5.8
Concord	25,228	59	1.9
Franklin	6,576	85	0.5
Laconia	12,471	100	0.9
Nashua River			
Clinton[2]	12,817	60	1.0
Leominster[2]	21,810	67	1.6
Fitchburg[2]	40,692	72	3.1
Total	328,125		24.7[3]

[1]Based on 75 g.p.d. per capita and exclusive of industrial wastes.
[2]Sewage treated.
[3]Probably as many as 15,000 persons in other municipalities discharge sewage directly into river or its tributaries.

sewage discharged. The effect of the pollution from the several sources upon the bacterial quality of the raw water at the Lawrence filter plant is shown in Table 3, which gives the annual averages of

TABLE 3.—ANNUAL AVERAGES OF COLIFORM ORGANISMS AT INTAKE OF LAWRENCE FILTER PLANT

(Massachusetts Department of Public Health—Annual Reports)

YEAR	B. COLI PER 100 C.C.	YEAR	COLIFORMS PER 100 C.C.
1919	19,400	1929	3,400
1920	11,800	1930	5,000
1921	18,000	1931	5,200
1922	6,900	1932	5,100
1923	7,200	1933	8,800
1924	6,600	1934	14,800
1925	5,700	1935	11,800
1926	6,700	1936	10,900
1927	4,500	1937	7,100
1928	4,200	1938	16,800

TABLE 4.—COMPARISON OF NUMBERS OF COLIFORM ORGANISMS IN RAW WATERS AT LAWRENCE AND AT SEVENTEEN[1] OTHER U. S. MUNICIPALITIES (1923-1924)

PLACE	RIVER	COLIFORM BACTERIA PER 100 C.C., 12-MONTH AVERAGE
Chester, Pa.	Delaware	20,500
Albany, N. Y.	Hudson[3]	19,400
Ironton, O.	Ohio	14,900
Ashland, Ky.	Ohio	11,400
Elmira, N. Y.	Chemung	9,450
Niagara Falls, N. Y.	Niagara	8,290
Youngstown, O.	Mahoning[3]	6,930
Lawrence, Mass. [2]	*Merrimac*	6,600
Evansville, Ind.	Ohio	3,940
Portsmouth, O.	Ohio	3,490
Cincinnati, O.	Ohio	2,980
East Liverpool, O.	Ohio	2,680
Huntington, W. Va.	Ohio	2,370
Louisville, Ky.	Ohio	2,220
Henderson, Ky.	Ohio	1,740
Toledo, O.	Maumee	1.650
New Milford, N. J.	Impounding reservoir	485
Steubenville, O.	Ohio	333

[1](H. W. Streeter, U. S. Pub. Health Bull. No. 172)
[2]For year 1924
[3]Source now abandoned

coliform organisms in the raw water as determined by the Massachusetts Department of Public Health. It is also interesting to compare the numbers of coliform bacteria in the raw water at Lawrence with those in the raw waters of certain other United States rivers at points where they are used for sources of supply. This is done in Table 4.

It is probably true that the raw water supply of Lawrence is more seriously polluted than any other source used for public water supply purposes in New England, and that it ranks as one of the most heavily polluted of the raw water supplies in the United States.

The unsatisfactory character of the raw water and the difficulties inherent in properly treating the supply by means of the existing slow sand filters led the State Department of Public Health to advise the city to secure a new source of supply. The Department of Public Health favored the Salmon River as an adequate and suitable source, but this involved such a large development cost,—well over four million dollars,—that it was beyond the ability of the city to follow the advice of the Department. The flooding of the filter plant and pumping station in 1936, however, resulted in the undertaking of the improvements herein described.

Although the abandonment of the Merrimac River as a source of supply and the development of a new and much less polluted supply would have been desirable, the cost involved would have been so great that retention of the river supply and improved purification facilities appeared to be the only practicable course to pursue. In view of the character of the raw water, it was decided to retain the existing covered sand filters for secondary filtration and to construct a modern rapid sand filter plant adjacent to the old filters, for primary filtration. The program of improvements involved also new low-lift and high-lift pumping stations, the raising of the river dike protecting the slow sand filters and the pumping station, and other incidental changes.

Double filtration has been employed in very few cases. Perhaps the best known examples are the Hudson River filter plant at Albany, N. Y., now abandoned, and certain of the London, England, plants. In the London plants the primary filters are of the rapid sand type, but are used without coagulants. The Lawrence rapid filters, however, employ coagulation and afford complete treatment, the slow sand filters being retained primarily as a safeguard against possible failure of the primary filters to produce a uniformly safe supply.

New Rapid Filters and Appurtenant Works

General. The design of the new filters and other structures was begun in the Fall of 1936. The dates of the letting of the four major construction contracts are shown in the following tabulation:

	Contract	*Date*
No. 1	Coagulation and sedimentation basin	Dec. 26, 1936
No. 2	Chemical and filter building, raw-water pumping station, aerators and appurtenances	Apr. 27, 1937
No. 3	Main pumping station	Jan. 21, 1938
No. 4	River dike, miscellaneous grading and paving	Aug. 10, 1938

The plant was completed and put into operation on December 16, 1938.

Basic Data. The principal basic data of design are contained in Table 5, and the general plan of the works is outlined in Figure 2.

Table 5.—Basic Design Data

Plant Capacity
- Design ..... 10 m.g.d.
- Present filter equipment ..... 8 m.g.d.

Raw-Water Pumping Station
- Intake screens, mechanical, Chain Belt Co. ..... 2 units
- Raw-water pumps, Allis-Chalmers vertical centrifugal
  - 1 unit, 30-ft. ..... 5 m.g.d
  - 1 unit, 30-ft. ..... 6 m.g.d
  - 1 unit, 30-ft. ..... 7 m.g.d
  - Space for fourth unit
- Yard-drainage pump, Yeoman's Bros. vertical centrifugal, 23-ft. ..... 1,000 g.p.m.

Raw-Water Venturi Meter, Builders Iron Foundry ..... 30 in. by 14 in.

Rapid Sand Filtration Plant
- Water-level controller, 24-in. Dow Pivot Valve, Chapman Valve Mfg. Co., hydraulic operation, dual-float control.
- Chemical-feed equipment dry-feed machines, Syntron Co.
  - Alum ..... 2 units
  - Lime ..... 2 units
  - Activated carbon ..... 1 unit
  - Spare ..... 1 unit
- Chlorination, Wallace & Tiernan Co., manual-control, solution-feed machines ..... 2 units
- Otis freight elevator to chemical storage and chlorination room on second floor.

TABLE 5.—BASIC DESIGN DATA—*Continued*

Mixing tanks	2 units
Dimensions 20 ft. by 20 ft. by 18 ft. water depth.	
Agitation New England Tank and Tower Co. vertical shaft paddles	0.5 to 2.0 r.p.m.
Operation in series or parallel	
Detention, at 10 m.g.d. in series	15 min.
Coagulation Basins	5 units
Dimensions 95 ft. by 33 ft. by (14 to 16.5 ft.) water depth	
Detention at 10 m.g.d.	4 hr.
Flocculators, Dorr Co. in first quarter of each basin	
Number of paddles in each basin	3
Diameter	11 ft.
Peripheral speed	25 to 100 f.p.m.
Settled-water pump, Allis Chalmers Co., 23-ft.	400 g.p.m.
Filters (2 not equipped)	10 units
Sand area, each unit 18 ft. by 20 ft.-4 in.	
Normal capacity per unit	1 m.g.d.
Underdrains, perforated cast-iron pipe	
Depth of graded gravel	18 in.
Depth of sand	30 in.
Depth of water over sand	5 ft.
Wash-water trough weir above sand	30 in.
Effective size of sand	0.46 m.m.
Uniformity coefficient	1.9
Rate controllers, 10-in. self-contained, Builders Iron Foundry.	
Operating tables, Norwood Engineering Co., each for control of 5 hydraulic valves	10 units
Wash Water	
2 pumps, Allis-Chalmers vertical centrifugal 45-ft.	10 m.g.d.
Rate controller, 24-in. Builders Iron Foundry.	
Back-washing rate	24 to 34 in. per min.
Surface wash, 42 nozzles, rate adjusted by hydraulic valve.	
Suction reservoir, beneath 4 southerly filters, capacity	125,000 gal.
Aëration	
Nozzles, Sacramento type, 2-lb. cone	70 units
Head at nozzles	4 ft.
Capacity per nozzle	100 g.p.m.
Secondary Filtration on Existing Covered Slow Sand Filters	
Area—west filter	0.73 acre
north filter	0.75 acre
east filter	0.77 acre
Total	2.25 acres

TABLE 5.—BASIC DESIGN DATA—*Continued*

Rate, at 10 m.g.d.	4.4 m.g.d./acre
Filtered Water Suction Reservoir	
In southwest corner of north covered filter—capacity	70,000 gal.
Main Pumping Station	
Existing low-service horizontal centrifugal pumps	
2 Fairbanks-Morse Co., each 195-ft.	6 m.g.d.
1 Lawrence Machine and Pump Co., 195-ft	6 m.g.d.
High-service horizontal centrifugal booster-pumps	
1 existing Lawrence Machine and Pump Co., 136-ft.	2.6 m.g.d.
1 new Lawrence Machine and Pump Co., 170-ft.	2 m.g.d.
Space for future unit	
Disinfection	
Wallace & Tiernan Co. manual-control, vacuum solution-feed chlorinators	2 units
Space for future ammoniator	
Venturi Meters	
Low-service—Builders Iron Foundry	24 in. by 10 in.
High-service—Builders Iron Foundry	16 in. by 8 in.
Miscellaneous	
Piping arranged to permit bypassing aërator or slow sand filters or both.	
Drainage of wash water and coagulation basins into river.	
Heating of all buildings from central-oil-fired steam-heating boilers in pumping station.	
Laboratory for routine plant control and for chemical and bacterial analyses.	

The filtration plant and appurtenant works including pumping stations for raw water and distribution, are essentially conventional in design. However, there were involved numerous complications related to the planning of the work in order to avoid undue interference with the continuous operation of the existing waterworks. Some problems were also involved in the inclusion of devices for providing adequate flexibility in operation to follow the expected seasonal changes in raw water.

Intake and Raw-Water Pumping Station. The normal river elevations fluctuate but little, due to the presence of the power dam of the Essex Company a short distance downstream. The intake channel, however, is placed low enough to assure a supply of water at the lowest probable river level and the vertical centrifugal raw-water pumps are also located so as to be self-priming under similar conditions. The motor floor of the raw-water pumping station on the other hand, is about 3 ft. above the 1936 flood level and the sub-

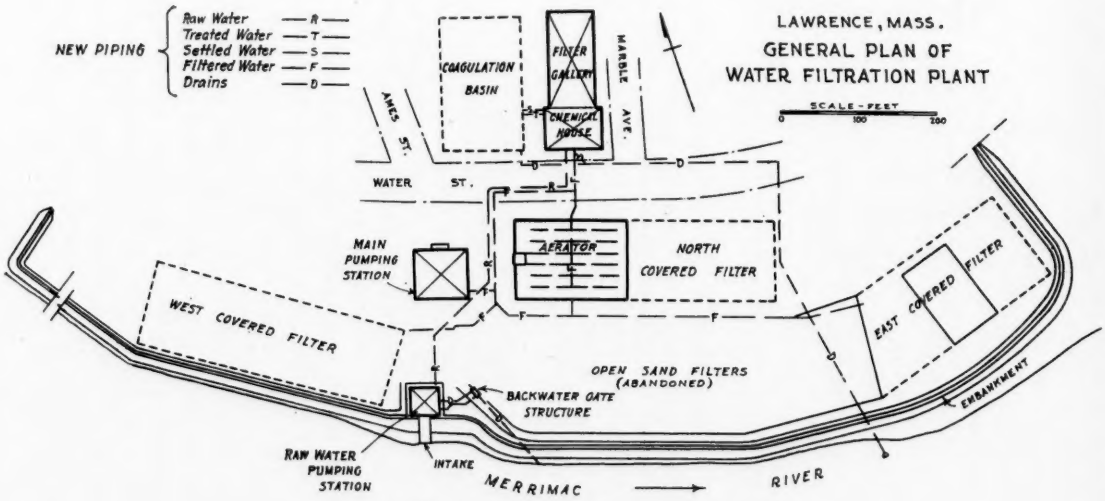

FIG. 2.—GENERAL PLAN OF FILTRATION PLANT.

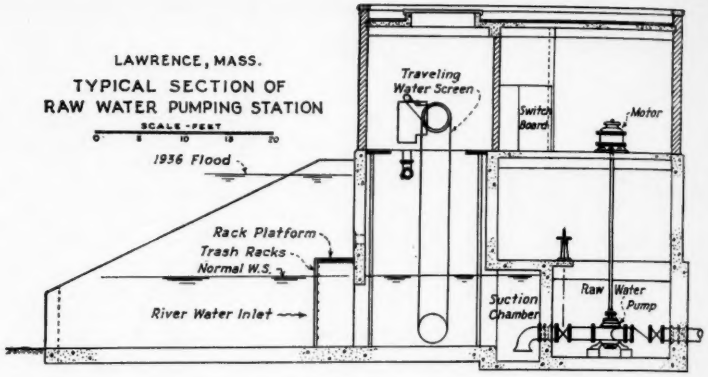

FIG. 3.—TYPICAL SECTION OF RAW-WATER PUMPING STATION.

structure is designed to withstand flood conditions. Figure 3 illustrates a typical section through this station. The existing dike has been raised from 5 to 6 ft., so as to provide a freeboard of about 2 ft. above the 1936 flood stage of the river, and extended to enclose the waterworks property.

The intake and raw-water pumping station are located at the river bank and the foundation is on the fine silty sand beneath the prism of the old dike. On account of the character of this material, and also better to resist the buoyancy of flood stages, the substructure of the station is designed and built as a heavy watertight box, the floor and walls of which act together as a rigid unit. Some difficulty was experienced during construction, due to the instability of the silty material when the hydraulic head was unbalanced by excavation and pumping within the cofferdam, which was constructed of light-weight corrugated-iron sheet-piling driven on the riverward side of the site. The situation was finally controlled by the use of well points and by providing a thin layer of gravel over the bottom to form a suitable surface on which to work prior to placing the bottom concrete. The new intake was built independent of the existing structure, to avoid interference with operation of the old plant during construction of the new; this also made possible a free hand in providing up-to-date facilities without regard to the limitations of old structures.

As the river water flows through the intake channel it first encounters a trash rack with 4 in. bar spacing, intended to intercept

large and unusual objects, which are removed when necessary by hand from a grating platform above the rack. The water then passes through travelling screens with copper wire mesh having ⅜-in. clear openings. These screens are in duplicate and were made by the Chain Belt Company. They are motor-driven and are cleaned by water spray which dislodges material caught on the mesh and washes it back to the river through a drain provided for that purpose. The screens are not run continuously but are rotated and washed at intervals which will vary widely as the quantity of trash present in the river varies. Stop planks are provided and may be installed to isolate either screen for unwatering and ordinary repairs. Should major repairs be necessary, an entire screen unit may be withdrawn by removing a hatch in the roof above and using a temporary hoisting rig.

The raw-water pumps, three in number, with space for a fourth, are vertical Allis-Chalmers centrifugal units with shafts extended to 2200-volt, 3-phase, 60-cycle squirrel-cage induction-motors about twenty feet above. The pumps have capacities of 5, 6 and 7 m.g.d. respectively, and discharge through a 30-in. cast-iron pipe to the filter-plant mixing tanks, the water surface in which is about 26 ft. above nominal river level.

Power is supplied from a switchboard located on the ground floor in the motor room and fed from the main switchboard in the main pumping station. The raw-water pumping units are normally started and stopped from remote-control switches in the office of the filtration plant, but they may also be operated from the nearby switchboard.

The raw-water pumping station also houses a yard-drainage pump for unwatering the grounds behind the dike when the river is in flood. Surface water from the yard is normally drained to the river by gravity though a backwater-gate manhole; but at flood stages the river is locked out of the main drain-pipe by double flap-valves in the manhole, and surface water is diverted into a chamber in the pumping station from which it is automatically pumped to the river.

A Builders Iron Foundry 30-in by 14-in. Venturi tube connected with a Chronoflo transmitter placed in the basement of the nearby station is located in the 30-in. cast-iron pipe leading from the raw-water pumps to the mixing tanks of the filtration plant where this pipe passes the main distribution pumping station. The transmitter electrically actuates a recorder in the office of the filtration plant where the rate of delivery of raw water to the plant can be observed by the filter plant operator.

Water-Level Controller. The inflow of raw water to the plant is kept in step with the combined output of the several filter units by means of a hydraulically-operated Dow pivot-valve in the raw-water pipe ahead of the mixing tanks. The throttling action of this valve is controlled by a pilot valve actuated both by the water level in the mixing tanks and by that on the filters. It has been found, in plants which control only from the level on the filters, that the time lag between the demand for water when the level drops and the satisfaction of this demand by the flow of additional water all the way through mixing and coagulation basins, is often such as to result in surges of inflow rate. With the dual control, which was developed by the Norwood Engineering Co. to meet the specifications for this plant, the opening of the throttling valve due to lowering of the water surface on the filters is promptly checked by the rise in mixing-tank water-level before the inflow rate can unduly increase.

Chemical Feed and Storage. Dry chemicals are fed by six machines of the pulsating electro-magnetic type, model CFM1-30 of the Syntron Company. Alum, lime and activated carbon are fed into the mixing tanks, and lime can also be fed into the settled water or into the filtered water by the manipulation of certain pipe connections, with proper safeguards to avoid possibility of cross-connection from raw to filtered water through this piping.

Extension hoppers are provided above the machines, connected with openings in the floor above, where chemicals are stored in quantity and charged into the hoppers as needed. After the initial installation, electro-magnetic Syntron vibrators were added to the extension hoppers of the lime and activated carbon machines and have successfully eliminated a tendency of these materials to "bridge" and hang up before reaching the influence of the agitators in the feed machines proper. This modification is advantageous as a labor-saver, since it obviates the necessity of punching down the material in the extension hoppers from time to time and assures a supply of chemical in the feed machines themselves as long as the extension hoppers are kept supplied. The chemical feed machines standing beside the mixing tanks, may be seen in Figure 4.

Chlorination is provided by two Wallace & Tiernan, Type MSVM, manual-control, visible-vacuum, solution-feed chlorinators, arranged to feed chlorine either to the mixing tanks for pre-chlorination, or to the filtered water, or both. The chlorinators are located in a special room off the chemical-storage room, isolating the effects of accidental leakage of chlorine.

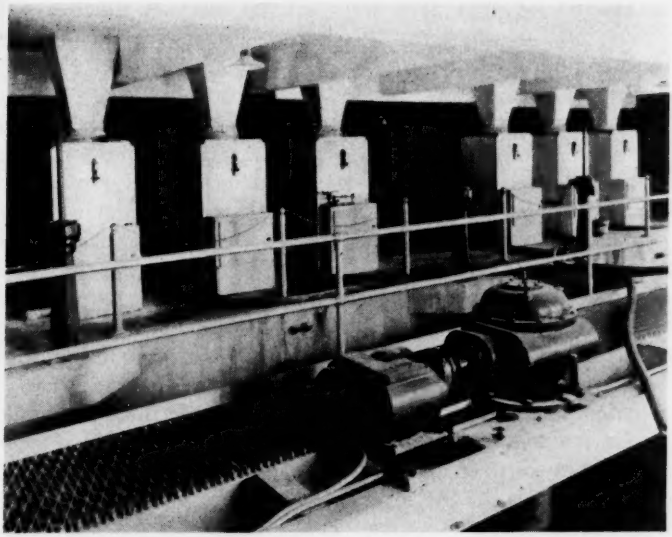

FIG. 4.—CHEMICAL FEED MACHINES AND MIXING BASINS.

An Otis freight elevator is provided to transport chemicals from the ground floor to the storage room level. Trucks can back up to an unloading platform on the east side of the building and an entry room is available inside a rolling steel door so that chemicals can be quickly unloaded and sheltered in stormy weather and then gradually loaded onto the elevator for transportation aloft at the convenience of the staff.

Mixing Tanks. The concrete mixing tanks are in duplicate and are arranged to be operated either in series or in parallel by the proper manipulation of gates. This arrangement also permits one tank to be drained for service or repair while the other is continued in use, avoiding interruption of plant operation. Mixing paddles are provided in each tank. These mechanisms, furnished by the New England Tank & Tower Company, consist of motor-driven, variable-speed, fully-enclosed Reeves drives from which are suspended paddles which are entirely of wood below water level, except that fastenings are of non-corrosive metal. The speed of the paddles is relatively slow, ranging from about 0.5 to 2.0 r.p.m.

In the construction of these tanks, as also in other concrete

structures intended to contain water, special care was taken to make them substantially watertight. Construction joints were made with steel cut-off plates, and vibrators were used to assure consolidation and density of the concrete.

Coagulation and Sedimentation Basins. From the mixing tanks, treated water flows to five coagulation and sedimentation basins, served by influent, effluent and drain conduits in a common headwall, and controlled by sluice gates. The flow is "around-the-end," each tank having a wooden baffle wall in the longitudinal center to direct the flow.

In order that means may be at hand to encourage flocculation if at any time floc cannot be satisfactorily formed in the mixing tanks due to peculiarities of the raw water, each basin is equipped with a Dorr Company Flocculator consisting of three paddle wheels in series, with horizontal axles at right angles to the direction of flow, the blades moving against the flow below the horizontal diameter. Wooden baffles between paddle wheels extend from the top of the basins down nearly to the level of the axles, cutting off the short-circuiting which might otherwise occur over the tops of the paddles where the blades move with the flow. The Flocculators have variable-speed drives so that they are capable of adjustment to give peripheral speeds from 25 to 100 ft. per minute on the 11-ft. diameter paddles. The basins are covered. This required that the Flocculators be so designed that when disassembled the component parts could be entered or removed through 36-in. manholes provided for access.

The basins are designed to be cleaned at intervals by draining and flushing. In order to waste a minimum of treated water when a basin is drawn down for cleaning, a pump is provided in the basement of the chemical building by means of which the top water in any basin can be withdrawn and returned to the treated-water main ahead of the basins remaining in service, before the drain valves are opened, permitting the remainder of the contents to enter the main drain leading to the river. The tanks are then entered and flushed out with hose streams.

Rapid Sand Filters. There are ten filter boxes, located five on either side of a pipe gallery. This gallery is arranged to provide an unobstructed walkway through its entire length, thus giving easy access to equipment such as rate controllers, hydraulic valves and loss-of-head devices. This accessibility is believed to be important as an aid to maintenance and to effective and flexible operation. A typical section across the pipe gallery is shown in Figure 5, and this gallery is further illustrated in Figure 6.

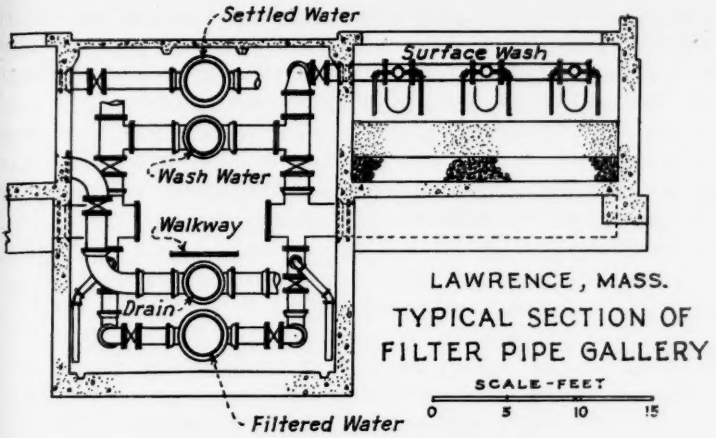

FIG. 5.—TYPICAL SECTION ACROSS PIPE GALLERY.

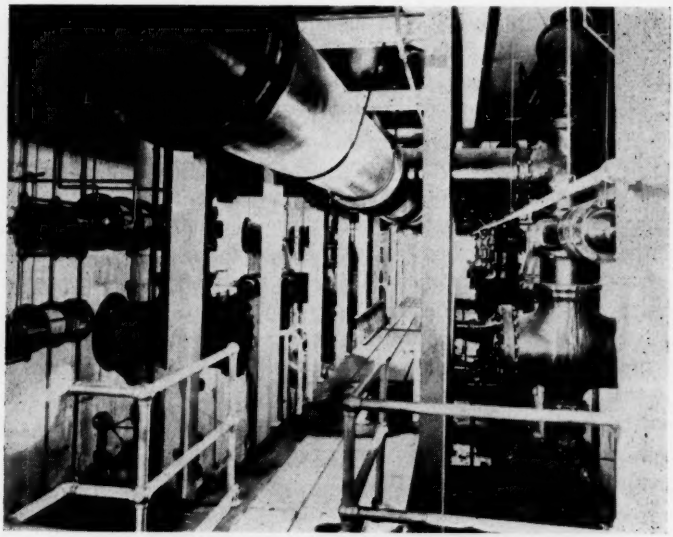

FIG. 6.—VIEW DOWN PIPE GALLERY.

The filter-underdrain systems consist of 3-in. cast-iron pipe-laterals, 6-in. on centers, with ¼-in. perforations 6 in. apart in each

of two lines about 30 degrees either side of the vertical axis on the underside of the pipe. Each pair of laterals feeds through a tee into a concrete header which, in turn, is connected with the filtered-water and wash-water piping at the face of the gallery wall.

The sand area of each box is 18 ft. by 20 ft.-4 in. Four layers of graded gravel, totaling a depth of 18 in., are placed around and over the pipe grid. The specified sizes and depths of the underdrain gravel are given in the following tabulation:

Layer	Depth (Inches)	Size of opening through which gravel will pass	Size of opening through which gravel will not pass
Bottom	7	2½-in. ring	1½-in. ring
2	4	1½-in. ring	¾-in. square
3	4	¾-in. square	¼-in. square
Top	3	¼-in. square	No. 12 mesh

The sand, which was obtained from the sea near Plum Island, is 33 in. deep. It has an effective size of 0.46 m.m. and a uniformity coefficient of about 1.9. It is expected that about 3 in. will eventually be skimmed off to remove not only foreign matter such as bits of seaweed and shell, but also any excessively fine material which gradually works its way to the top, leaving the final sand depth 30 inches.

Provision is made for washing the filters by back-washing in the conventional manner through the underdrain system and also, as an auxiliary method, by surface washing. The latter is accomplished after the manner described by John R. Baylis in a paper read before this Association in September 1936. A system of pipes serves nozzles spaced 3 ft. apart in each direction, about 4 in. above the ultimate sand surface. Each nozzle directs one ¼-in. jet straight down and four similar jets downwards and outwards at about 52 degrees with the vertical. The surface wash, as well as the backwash, is controlled by hydraulic valves actuated from the operating tables. Any desired sequence of surface- and back-washing can be obtained by the manipulation of these valves.

Wash water under suitable pressure is provided by either of two 10-m.g.d. Allis-Chalmers vertical centrifugal pumps. These pumps discharge into the main wash-water pipe through a 24-in. Builders Iron Foundry rate-controller by means of which the rate can be limited according to the adjustment of controller. Wash-water rates can be adjusted between 24 and 34 in. of vertical rise per minute.

One important function of this controller is to avoid upsetting the filter gravel by excessive backwash rates. Special devices are provided so that the wash-water rate-controller is in the closed position when pumping starts, rather than in the wide-open position which rate controllers normally assume when there is no flow. This insures against the occurrence of excessive rates in the short interval before the controller can throttle down from the wide-open position. Whether the complications introduced by the auxiliary closing device are worth while is debatable. It may be urged that a properly instructed operator can be trained to open the wash-water valve from the operating table slowly, so as to give the controller time to adjust itself before the full force of the wash can be felt in the filter bed. On the other hand, an absent-minded or careless operator can disrupt a filter in a few seconds, causing expensive and laborious reconstruction of the graded layers of the entire bed.

Wash-water pumps may be started and stopped when needed by remote-control switches at the end of the operating gallery, and a large illuminated dial on the end wall gives opportunity to observe the rate of wash at any instant, as a check on the controller.

Wash-water suction-reservoirs beneath the four most southerly filters, replenished through an automatic valve from the main filtered-water pipe and containing water enough for two or three washes, supply the wash-water pumps and prevent undue intermittent draft upon the filtered-water main.

Filter operating-tables made by the Norwood Engineering Co. are located opposite each filter unit and contain operating levers for the hydraulic valves on influent, effluent, drain, surface-wash, and backwash pipes. On the table are also located Builders Iron Foundry illuminated instruments indicating the loss of head through the filter, and recording the rate of filtration. Figure 7 is taken looking lengthwise of the filter-operating gallery. Each filter unit is equipped with a 10-in. Builders Iron Foundry, adjustable, self-contained rate-controller on the filtered-water outlet-pipe.

Dirty wash water is discharged into the river below the plant through a main drain which also serves the coagulation basins. The main drain lies below the maximum flood level of the river, and hence it is constructed of cast iron inside the building and of reinforced-concrete pressure-pipe outside. Water falling on the floor of the pipe gallery and chemical building basement from hydraulic valve wastes, chlorinator overflow, condensation, etc. is collected in

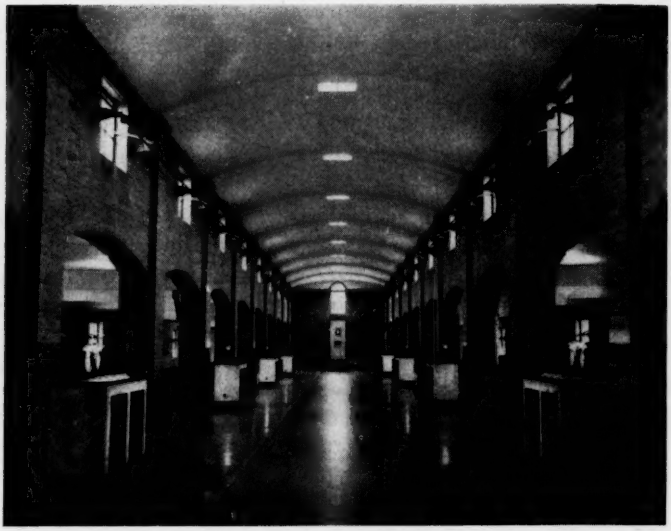

FIG. 7.—VIEW DOWN OPERATING GALLERY.

FIG. 8.—AËRATOR AND PUMPING STATIONS.

gutters leading to sumps from which automatic sump pumps eject it into the main drain.

On a panel in the plant office are instruments recording the rate of pumping of raw water and of wash water, and water levels in the wash-water suction-reservoir and on the old slow sand filters. From this panel the raw-water pumps can be started and stopped.

Adjacent to the office is the laboratory, completely equipped for all functions necessary for directing the operation of the plant and determining its effectiveness.

Aërator. Across the street from the rapid sand filtration plant, occupying part of the roof of the old, north, covered, slow sand filter is a low-head spray aërator, Figure 8, through which the filtered water can be passed, when taste or odor conditions require it, on the way to secondary filtration through the existing slow sand filters. Spraying is accomplished by 70 nozzles of the Sacramento type, and the concrete floor of the aërator is sloped to conduct the water falling on it to an outlet from which it is conveyed to the slow sand filters, or direct to the distribution pumping station.

The nozzles operate under a head of about 4 ft. and at that head have a capacity of 100 g.p.m. each. The water enters the aërator through a header to which twelve laterals are connected. The nozzles are mounted on the laterals, each of which is controlled by a valve, so that the number of nozzles in service can be proportioned to the rate of filtration.

The aërator floor was constructed by first covering a portion of the concrete roof of the north covered filter with 3 in. of corkboard bedded in and flushed with hot asphalt, as insulation against freezing of the water on the filter beneath; concrete was then placed of varying thickness, to give the desired slope for drainage. The aërator is surrounded by a fence of corrugated Transite with sloping apron at the bottom, to limit loss of water by wind-driven spray, while admitting air freely along the bottom edge of the fence for ventilation and dissipation of odors released within the enclosed area.

Slow Sand Filters. No changes were made in the existing covered slow sand filters except to reconnect the inlets to receive effluent from the new rapid sand filter plant, and to partition off one corner of the north covered filter, removing the sand, and converting it into a small filtered-water reservoir of about 70,000 gal. capacity. This reservoir is intended only to take up the surge of pump demand on starting a pump in the main distribution pumping station until the inertia of initial or increasing flow through the slow sand filters is

overcome. The old open slow sand filters having been abandoned, the space they occupy is available for the future construction of a larger and more adequate filtered-water reservoir.

Main Distribution Pumping Station. The new main pumping station is on the identical site, and on the foundations of the old station built in 1874. Its construction involved the problem of dismantling the old Leavitt steam pumping-engine and its foundations, tearing down the old station, modifying the substructure within the old foundations, erecting an entirely new superstructure, building a new system of suction and discharge piping, and moving the existing electric-motor-driven centrifugal pumps to new positions, without interrupting the supply of water to the city. Pumping was carried on every day during construction, except during the last stages of making the final changes from the old to the new layout, it was necessary to discontinue pumping for a few periods of one or two days each, in anticipation of which the high- and low-service distribution reservoirs were well filled in advance. These reservoirs have capacity for the storage of several days' demand.

About one-half of the lower level of the pumping station is occupied by pumping units and related piping. Part of the lower floor area is utilized for miscellaneous station-service equipment and for the central heating plant which serves the filtration plant and raw-water pumping station as well as the main pumping station; the remaining space is equipped with toilet facilities and is available as a mess room for the outside crew and miscellaneous laborers.

On the main floor, which is omitted in the area immediately above the pumps, are located a switchboard and operating gallery, a chlorination room, an office, toilet and locker rooms for the operating engineers. The dimensions of the old foundations were such as to make available also a large room on the main floor which has been fitted with polling booths and which will be utilized as a precinct polling place, superseding a small portable building previously used for this purpose.

Pumping Units. The low-service pumps consist of two 6-m.g.d. Fairbanks-Morse centrifugal pumps with 250-hp. synchronous motors from the equipment of the old station, and one 6-m.g.d. Lawrence centrifugal pump with 300-hp. Westinghouse squirrel-cage motor, also from the old station, but entirely rebuilt, with new impeller. The latter unit is held in reserve. These pumps discharge directly into the 40-m.g. low-service reservoir built in 1875 on Tower Hill, north of the plant, from which the low-service distribution areas are fed.

The high-service pumps consist of one new 2-m.g.d. Lawrence centrifugal pump with 75-hp. General Electric synchronous motor and one old 2.6-m.g.d. motor-driven Lawrence centrifugal pump held in reserve. These pumps take suction from the low-service distribution system and discharge into the high-service system on which a 529,000-gal. high-service standpipe floats, also located on Tower Hill. Provision is also made in the pumping station for taking the suction of the high-service pumps directly from the low-service pump discharge header, if necessary in an emergency. A partial view of the low- and high-service pumping equipment is shown in Figure 9. Space is pro-

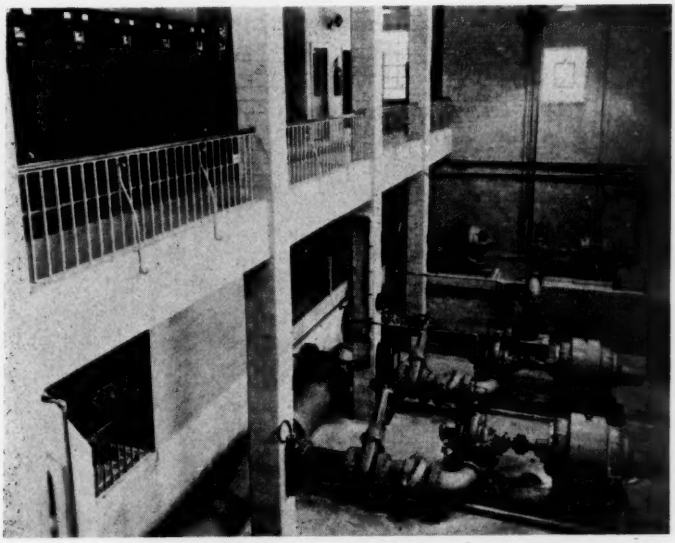

FIG. 9.—HIGH- AND LOW-SERVICE PUMPS.

vided for a third high-service pumping unit to be installed in the future.

Priming System. The low-service pumps, which ordinarily operate with a suction lift, are automatically primed. For this purpose they are connected to a vacuum tank which is automatically held at the required vacuum by a Nash motor-driven vacuum pump. As a further safeguard, the priming system may be evacuated by a manually-operated water-jet eductor, in case the vacuum pump is out of service for any reason.

Venturi Meters. In trenches beneath the basement floor, on both high-service and low-service discharge pipes, are Builders Iron Foundry Venturi tubes. That on the low-service main is a 24-in. by 10-in. tube and that on the high-service main 16-in. by 8-in. Register-indicator-recorders for both of these tubes are located on the easterly end of the main operating or switchboard-gallery.

Switchboard. Electric current at 2200-volt, 3-phase, 60-cycle, is brought into the main pumping station to the main switchboard from which it is distributed not only to the electrical units in the station but also to the raw-water pumping station and to the filtration plant. The board, part of which can be seen in Figure 9, is of the dead-front type and was manufactured by the Allis-Chalmers Manufacturing Company. The auxiliary switchboards in the other buildings are of the same make.

In an enclosure on the floor below the main switchboard are transformers for lighting and miscellaneous service both in the distribution pumping station and in the raw-water pumping station, reducing the voltage from 2200 volts to 120-208 volts. These transformers are of the non-inflammable type, being filled with a special synthetic liquid so that indoor installation is permissible without many of the special precautions required for the usual type of oil-filled transformer.

Disinfection. Final disinfection of the water leaving the distribution pumping station is effected by means of Wallace & Tiernan, manual, solution-feed chlorinators located in a separate room at the east side of the pumping station, chlorine being introduced into the suction main of the low-service pumps. Space and other provisions are available for the future installation of ammonia equipment. Chlorine cylinders may be transferred from trucks directly into the chlorine room through a special outside door, the sill of which is at convenient loading height.

Central Heating Plant. In the basement of the distribution pumping station are two Knowlton steel boilers with copper water tubes equipped with fuel-oil burners. As previously noted, these boilers supply steam for heating not only the distribution pumping station, but also the raw-water pumping station and the filtration plant. Both unit-heaters and cast-iron radiation are used throughout the plant. The former are used in the larger open spaces and the latter in the smaller rooms.

Steam supply and return pipes are laid between the buildings underground. Due to the fact that at high river stages the ground

may be saturated, underground pipes were installed according to the Durant system, wherein the pipe covering is prefabricated and consists of 2 in. of 85% magnesia insulation outside of which is 1 in. of nonporous, high-melting-temperature, waterproof, asphalt compound, the whole being encased in a tight-fitting jacket of galvanized iron. Joints are similarly made in the field, so that the waterproofing is continuous.

Automatic pumps for discharging station sewage into the street sewer are also located in the boiler room, as are drainage pumps for unwatering the low points in the station substructure.

An exterior view of the new filter plant is shown in Figure 10.

FIG. 10.—EXTERIOR VIEW OF RAPID FILTER PLANT.

OPERATION OF SAND FILTERS

The rapid sand filters were put into regular service on December 16, 1938. For the first six months, operation of the new filters was under the direction of the designing engineers, with Mr. John S. Bethel of their staff as resident operator. During these months the various minor difficulties that always occur when new plants are started were ironed out and experience obtained as to the best methods of operation, particularly as regards chemical dosages. The operation period

covered by the following discussion is that for the first half of 1939.

Coagulation and Floccuation. The two mixing tanks during the period were operated in series. The detention periods in these basins have varied according to the quantities of water treated, the average period being about 40 min. The paddle in the first tank was operated at a higher rate of revolution than that in the second tank.

Coagulating chemicals, as well as activated carbon when used, have been applied to the raw water in these tanks. Coagulation has usually been effected by alum alone, but at times, in April and May, it has been necessary to use lime to increase the alkalinity of the raw water. No difficulty has been experienced in securing a satisfactory floc. Table 6 gives a summary of the various chemicals used in treating the supply:

TABLE 6.—SUMMARY OF CHEMICALS APPLIED TO RAW AND FILTERED WATER
Pounds per million gallons.

		Lime			Chlorine		
Month	Alum	Pre-treatment	Post treatment	Carbon	Pre-treatment	Post treatment	Final treatment
January	141	0	48	2.4	4.3	0	1.9
February	140	0	50	5.3	4.0	0.3	5.8
March	149	0	44	0	3.9	0	5.3
April	152	17	56	0	3.9	0.1	5.6
May	144	3	64	0	3.6	1.1	4.6
June	178	0	57	0	4.0	1.0	3.7

Although no comparative tests have been run to determine the effectiveness of the alum with and without the flocculators, observations indicate that their use has facilitated clarification of the treated water. The flocculators have operated practically continuously during filter plant operation. The computed average detention period in the compartments of the sedimentation basins in which the flocculators are located, has approximated 2½ hours on the average.

Sedimentation. The total time of detention in the sedimentation basins has averaged about 10 hours of which 7½ hours were devoted solely to settling. The basins were cleaned between April 9 and 20 when approximately 27,200 cu. ft. of sludge were flushed to the river, equivalent to about 61 cu. ft. per m.g. of water treated. Table 7 shows analyses of the sludge removed from each basin.

Filtration. Due to the fact that the actual water consumption has been less than the capacity of the plant, it has not been necessary to operate the filters at their rated capacity except occasionally, nor

TABLE 7.—ANALYSES OF SLUDGE REMOVED FROM SEDIMENTATION BASINS, APRIL, 1939

Basin No.	1	2	3	4	5
Quantity of Sludge, cu. ft.	5150	6470	5150	5200	5220
Per cent solids					
Total	1.30	0.91	0.57	0.53	0.79
Volatile	0.70	0.52	0.33	0.28	0.45
Fixed	0.60	0.39	0.24	0.25	0.33
All sludges black from carbon but with slight musty odor only					

for 24 hours every day. The average rate of filtration has approximated 85 m.g. per acre daily, the wash water a little less than two per cent and the filter runs about 65 hours. Filter operating-data are summarized by months in Table 7.

Minor difficulties connected with tuning up mechanical equipment and breaking in inexperienced operators naturally occurred. However, there has been no serious difficulty in filter operation. The Baylis surface wash has been used frequently, but not at every wash. No evidence of mud-ball formation appeared during the period covered. The percent of wash water used has been low, and the runs between washings have been long, although it should be noted that the rates of filtration have been low and the period of sedimentation long. The practice has been to wash the filters when the loss of head through them has built up to approximately 9 ft.

TABLE 8.—SUMMARY OF RAPID SAND FILTER OPERATION

Month	Pumped from river, M.G.D.	Wash water, M.G.D.	Net yield, M.G.D.	Wash water %	Rate of filtration, M.G.D.	Average length of runs, hr.	Average loss of head—ft.	
							Initial*	Final
January	3.724	0.057	3.651	1.4	84	55	0.3	8.3
February	3.850	0.067	3.783	1.8	74	69	0.1	8.6
March	3.580	0.051	3.529	1.4	82	75	0.0	9.0
April	3.471	0.054	3.417	1.6	87	70	0.0	8.8
May	3.974	0.052	3.922	1.3	91	77	0.0	8.8
June	4.277	0.105	4.172	2.5	92	36	0.0	8.9

*Loss of head gages set to register zero with clean bed.

Corrosion Control. In view of the increase of carbon dioxide, due to alum treatment and the resulting increase in corrosive qualities of the treated water, lime has been continuously added to the filter effluent. The pH value of the raw river water has approximated 6.7, that of the treated and settled water, 5.7, and that of the

final effluent 7.2. So far as our information goes there has been no increase in the action of the supply upon mains or services.

Taste and Odor Control. In view of the large quantity of organic matter in the river, the occasional growth of algae and the presence of phenolic wastes from gas works, it has been one of the important functions of the new treatment processes to remove taste- and odor-producing substances. This has been accomplished in part by the basic coagulation and filtration processes, and in part by the occasional use of activated carbon. Most of the time it has not been necessary to use carbon and at no time has aeration been required, although it has been used to some extent.

Chlorination. As previously noted, provision is made for chlorination of the raw water at the mixing tanks, of the settled water ahead of the filters, of the effluent from the rapid filters and of the final effluent at the main pumping station. Prechlorination has been carried out practically all the time, but chlorination of the rapid filter effluent, except when the slow sand filters were not in use, has been seldom employed. Chlorination of the water pumped to the distribution reservoirs has been practiced at all times.

Prechlorination and rapid sand filtration have been adequate to produce effluents of satisfactory bacterial quality. Postchlorination and slow sand filtration, when used, have been additional measures for safeguarding the supply delivered to the distribution system. In practice, it has been the intent to prechlorinate sufficiently to secure not more than two positive presumptive tests out of five 10-c.c. inoculations. With final chlorination the criterion has been the maintenance of a chlorine residual of 0.10. p.p.m. in samples allowed to stand for 10 minutes and based upon the intensity of the color produced by orthotolidin 10 minutes after the application of the reagent.

Laboratory Control. The plant is equipped with a very complete laboratory in which the routine physical, chemical and bacterial analyses are made. Monthly summaries of the physical and chemical analyses are given in Table 9. This table shows that by rapid sand filtration the turbidity is reduced from about nine parts per million to zero, and the color from about thirty-three parts to about five parts. Odor and taste have been removed and an attractive palatable water produced.

Monthly summaries of bacterial analyses are given in Table 10. This table shows that on the average the 37° C., 24-hr. agar count was reduced from about 920 per c.c. to 4 per c.c. and the 20° C., 48-hr. agar count from about 4700 per c.c. to 10 per c.c. In the case of the

TABLE 9.—SUMMARY OF PHYSICAL AND CHEMICAL ANALYSES
All values, except pH, are parts per million.

MONTH	TURBIDITY		COLOR		pH VALUE			CARBON DIOXIDE		ALKALINITY		RESIDUAL CHLORINE TREATMENT		
	Raw	Filtered	Raw	Filtered	Raw	Settled	Filtered	Raw	Filtered	Raw	Filtered	Pre-	Post	Final
January	—	—	32	5	6.7	5.7	6.7	—	—	10.8	10.6	—	—	0.12
February	5	0	33	5	6.7	5.8	7.0	6.1	5.2	12.3	13.5	—	—	0.13
March	7	0	32	4	6.6	5.7	7.2	5.4	4.8	10.0	12.7	—	—	0.11
April	11	0	30	5	6.7	5.7	7.7	5.1	3.9	9.3	13.9	—	—	0.12
May	13	0	31	5	6.7	5.6	7.6	4.5	3.6	9.6	13.6	—	0.03	0.13
June	7	0	42	7	6.7	5.8	7.0	3.9	3.1	11.0	11.0	—	—	0.13

TABLE 10.—SUMMARY OF BACTERIAL ANALYSES

Month	TOTAL COUNT per cc. Agar 24 hr. at 37°C. River	Agar 24 hr. at 37°C. Rapid filter effluent	Agar 48 hr. at 20°C. River	Agar 48 hr. at 20°C. Rapid filter effluent	Agar 96 hr. at 20°C. River	Agar 96 hr. at 20°C. Rapid filter effluent
January	1,490	3	4,600	1	12,000	3
February	550	2	5,200	5	10,000	10
March	425	1	4,500	6	15,000	12
April	260	1	1,400	2	6,900	11
May	550	1	1,500	3	6,900	8
June	2,310	19	11,160	48	27,000	102

	COLIFORM ORGANISMS (Presumptive) Percent positive inoculations River			Rapid filtered effluent		
	0.001	0.01	0.1	1.0	1.0	10.0 c.c.
January	25	75	90	100	0	0
February	0	60	95	100	0	1
March	0	60	95	100	0	0
April	0	84	95	100	0	3
May	0	84	100	100	0	0
June	6	83	100	100	0	11

raw water, coliform organisms by the presumptive test have been found in the majority of the 0.01-c.c. dilutions and occasionally in the 0.001-c.c. dilutions. Out of 600 ten-cubic-centimeter inoculations from samples of the filtered water only 13 gave positive presumptive tests for coliform bacteria, or two per cent.

Double Filtration Tests at Lawrence Experiment Station. In order to furnish information to the Department of Public Health regarding double filtration of the Merrimac River water, a small pilot plant was put into operation on March 1, 1937, at the Lawrence

Experiment Station. Although the new city filters had been designed by the time this pilot plant was started, it is interesting to note that the results obtained were similar to those which have been obtained with the full-size plant.

Construction Costs. The following tabulation lists the contract costs:

Contract	Contractor	Cost
1. Coagulation Basins	C. H. Cunningham & Co., Inc.	$ 84,318.61
2. Filter Plant, Chemical Bldg.	James A. Monroe & Sons	415,367.60
3. Main Pumping Station	C. H. Cunningham & Co., Inc.	101,718.99
4. River Dike, Grading, etc.	O'Malley & Delaney	22,860.75
Total Construction Cost		$624,265.75
Laboratory Equipment, Furniture, etc.		3,795.90
Total		$628,061.85

The above cost does not include administration, legal expense, engineering, inspection, nor testing of materials.

Personnel. The work was undertaken and carried out under the administration of Mayor Walter A. Griffin, with Mr. Gordon E. Gaffney, Assistant City Clerk, acting as executive assistant in charge of all Federal-aid projects in the city. Mr. John T. Kilcourse was Director of Engineering at the initiation of the project and during the early stages of construction, and was succeeded by Mr. Daniel F. Ferris, the present Director. Mr. Patrick S. Nugent, a member of this Association, is Superintendent of Water Works, in general charge of the operation of the filtration plant. Mr. Joseph Derby has been chemist in direct charge of filter-plant operation since June 15, 1939.

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Discussion

BY FRANCIS H. KINGSBURY*

The Merrimack River at the Lawrence filter plant is known to be polluted to a degree which should preclude its use for water supply purposes if any other source were economically available. On more than one occasion the Massachusetts Department of Public Health has advised the city of Lawrence that the Merrimack River is an unsuitable source of water supply, and from time to time the Massachusetts Legislature has required the Department to investigate the water supply needs and resources of municipalities lying within the Merrimack River Valley. The city of Lawrence has from time to time obtained private consulting engineering advice in the investigation of its water supply problems, and all of these engineers have recommended a source of supply other than the Merrimack River.

In the legislative investigations conducted by the Department of Public Health it appeared feasible to supply the municipalities in the Merrimack River Valley in Massachusetts with water taken from the Metropolitan water supply at Wachusett Reservoir or to develop a water supply for these municipalities from Salmon Brook, a tributary of the Nashua River. The most feasible supply from any economic standpoint appeared to be Salmon Brook. These investigations were made immediately prior to the financial depression, but reduction in industrial activity during the depression resulted in a considerable decrease in water consumption, and the need of an additional water supply for these municipalities became less urgent.

The disastrous flood of 1936 in the Merrimack River Valley again focussed the attention of the municipalities on water supply matters. The slow sand filters at Lawrence were submerged by the flood waters, and large quantities of river silt were deposited on the open filters. The pressure of the flood waters burst the bulkheads leading to the covered filters with the result that these also received a large deposit of river silt, gradually reducing their capacity. After strenuous efforts on the part of the local officials and the engineering staff of the Department of Public Health, these facilities were reconditioned and placed in operation, but it had become apparent that these works were inadequate, and the question of rebuilding the open filters and increasing their capacity, protecting them against again being flooded by water from the Merrimack River, led to an economic study of the possibility of installing filters of the rapid sand type.

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After an investigation, the firm of Metcalf & Eddy, Consulting Engineers, reported to the city of Lawrence under date of June 9, 1936, and an outline of the general scheme of water treatment was submitted to the Department of Public Health. Under date of July 20, 1936, the Department stated that in its opinion the proposed general method of treatment of the water of the Merrimack River was an appropriate one for the city to adopt until a source of water supply other than the Merrimack River could be made available. The general scheme included in the report of the Engineers and submitted to the Department provided for the installation of rapid sand filters and the adaptation of the covered slow sand filters to provide double filtration of the water of the Merrimack River. The Department's approval of plans subsequently submitted was given expressly with the understanding that the covered slow sand filters would be adapted to receive the effluent from the rapid sand filters.

This matter of double filtration has been recently reviewed in response to the request of the Mayor of the City of Lawrence and the Department has stated that—

> ". . . . while works were installed for the treatment of the water of the Merrimack River by filtration resulting in a marked reduction in the number of cases of typhoid fever in the city, there continues to remain the danger of supplying water without proper filtration, should difficulties be experienced in the operation of the new filtration works or damage to the plant occur. The water of the Merrimack River contains a greater number of bacteria characteristic of pollution than is generally deemed acceptable for treatment at an ordinary water filtration plant and as late as August 5, 1936, the Department called your attention to a considerable number of typhoid fever cases in the city of Lowell at that time and to the fact that the sewage from the city of Lowell was being discharged directly into the Merrimack River without treatment."

And the Department has further stated that—

> ". . . . in its investigations with regard to the possibility of the city of Lawrence obtaining a suitable water supply from unpolluted sources, the Department has considered that the water filtration works of the city might be used in connection with such a supply. It was with this thought in mind that the Department reluctantly approved the continued use of the water of the Merrimack River after double

filtration and chlorination as the only source of supply within the means of the city at the time of approval. . . . ."

Experience in the operation of the rapid sand filters with chlorination since their completion has shown that the effluent has been of satisfactory quality, and the question of the necessity of the continued use of the covered slow sand filters for double filtration has been questioned. In answer, the Department of Public Health has stated that—

". . . . while the Merrimack River continues to be a source of water supply of the city of Lawrence and until water from an unpolluted source may be obtained, the Department must insist upon the use of the complete works. . . .'

SIGNIFICANT EXPERIENCES IN THE TREATMENT OF WATER IN NEW YORK STATE

BY C. R. COX*

[*Read September 14, 1939*]

There seems to be a definite tendency for writers on water works matters to stress successful accomplishments rather than unsolved problems or failures. This attitude ordinarily is justifiable in order that basic information may be made available to the profession. On the other hand, the diversity of problems created by exceptional conditions adds to the interest as well as to the difficulty of their solution. Because of this situation, it was deemed desirable to review some rather unusual problems in the treatment of water at three municipalities in New York State. It is not believed, of course, that conditions in New York State differ from those in the rest of the country but rather that this state is sufficiently large to include the occurrence of many unique conditions.

Water Ozonation Plant, Delhi, New York. The water supply of the village of Delhi was subjected to ozone treatment during the period 1928-1935. The conditions surrounding the selection of this unique type of treatment plant and subsequent operating experiences are worthy of comment.

The village of Delhi, with a population of about 1800, is supplied with surface water from an upland stream draining a natural lake. Treatment by filtration and disinfection is necessary for the production of attractive water of safe, sanitary quality. Recommendations to this effect were not acted upon prior to 1928, because of the failure of the citizens to support the necessary bond issue. Later it developed that this opposition was due to dislike of chlorination. Because of this situation, the water officials inspected the water treatment plant at Ogdensburg, New Jersey, where ozonating treatment was practiced at that time. Acting upon their favorable impression of this plant, a similar one was placed in operation at Delhi in 1928.

Briefly, the plant had a rated capacity of 0.75 m.g.d. and consisted of a cylindrical steel coagulation basin of 60,000-gal. capacity, two horizontal pressure-filters, 8 ft. by 16 ft. in size, a steel filtered-water storage-tank of 132,000-gal. capacity, and equipment for supplying

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alum, soda ash and ozone to the water. The capacity was considered more than ample for a village of this size, but consumption of water was found later to be very high due to leakage and industrial usage. Peak flows over 1.0 m.g.d. or 550 g.p.d. per capita were common. The plant was constructed at a cost of about $40,000. Itemized cost data are lacking.

The ozonating equipment was manufactured and the entire plant was designed and installed by the Electrozone Corporation of New York City. This equipment consisted of an activated-carbon dehydrating-unit for the filtration and dehydration of the air forced through two groups of twelve ozonating electrodes, each consisting of glass tubes 2 in. in diameter and 24 in. long. Aluminum electrodes were situated in the center of each cylinder, and other aluminum foil electrodes were wrapped outside the tubes. The tubes were submerged in a water bath for cooling purposes. Sixty-cycle current of 220 volts was increased by a transformer to several thousand volts, a voltage sufficient to cause "silent brush discharge" in the tubes but not so high as to cause "hot arcing." The ozonated air passing through these tubes was ejected into a portion of the water flowing through the top of two absorption towers 2½ ft. in diameter and 32 ft. high. The treated water was then conducted to the bottom of the absorption towers to facilitate the solution of ozone in water before mixing it with the main portion of filtered water.

The original ozone apparatus was supposed to have a capacity of 86 grams of ozone per hour, equivalent to about 0.7 p.p.m. for a flow of about 0.75 m.g.d. Sixty grams of ozone were supposed to be produced per kilowatt-hour of electricity, making the cost of ozone $0.20 to $0.30 per pound at the low current charge of $0.02 per kilowatt-hour. A dose of 0.5 p.p.m. of ozone was held to be adequate by the manufacturer, but this was proved to be incorrect.

Since the solubility of ozone in water is low, it was found that complete absorption could not be effected unless all of the water treated was forced through the absorption towers. This necessitated the installation, during the following year, of a centrifugal pump of 450-g.p.m. capacity, because the tops of the absorption towers were located above the hydraulic gradient of this gravity plant. An additional operating charge of $1800 per year for pumping was incurred.

It is difficult properly to appraise the results secured at this plant, because part of the failure was due to neglect of the equipment and lack of proper coagulation of the water to be filtered, and part to the difficulties inherent in ozonation equipment. It was found possible,

however, effectively to disinfect adequately filtered water when *sufficient* ozone was added. The water so treated had no residual taste or odor, and the organic matter it contained was bleached and oxidized.

Table 1 shows typical results secured when the ozonator was

TABLE 1—ANALYSES OF WATER SAMPLES COLLECTED BY R. D. BATES FROM DELHI, N. Y., WATER OZONATION PLANT ON FEBRUARY 20, 1929

	Raw Water	Filter Effluent	Base of Ozone Tower	Final Plant Effluent
Color	0	—	—	0
Odor, hot	1 veg.	—	—	1 veg.
Odor, cold	1 veg.	—	—	1 veg.
Turbidity	1	—	—	Trace
Nitrogen as:				
Free Ammonia	0.002	—	—	0.002
Albuminoid Ammonia	0.040	—	—	0.036
Nitrites	0.001	—	—	0.001
Nitrates	0.44	—	—	0.46
Oxygen consumed	2.5	—	—	1.7
Chlorides	1.2	—	—	1.2
Hardness, total	23.4	—	—	23.4
Alkalinity	12.0	—	—	12.5
Bacteria per c.c.:				
20°C.	70	Liquefied	Liquefied	30
37°C.	36	7	1	3
B. Coli type in:				
10cc.	3+0–	3+0–	0+3–	0+3–
1 cc.	2+1–	0+3–	0+3–	0+3–
1/10 cc.	0+3–	0+3–	0+3–	0+3–
1/100 cc.	0+3–	—	—	—

Chemical results are expressed in parts per million.

Abbreviation used to describe odors of water: 1 = very faint, v = vegetable.

+ *B. coli* present; – *B. coli* absent. 2+1– *B. coli* present in 2 and absent in 1 of 3 volumes tested.

functioning normally. On the other hand, it was found difficult, if not impossible, to regulate the output of the ozonator to compensate for changes in the organic content of the water (ozone demand), because the results of the starch iodide or orthotolidine tests were not quantitatively correct. In fact, consistent color production could not be secured, although ozone as an oxidizing agent did react with these indicators. Furthermore, the dehydrating equipment was inadequate, and thus dusty, moist air was forced through the ozone tubes with the result

that "hot sparking" occurred with reduction in efficiency and ultimate destruction of the apparatus. Periodic replacement of tubes, therefore, was necessary.

Because of the excessive cost of operation and replacement of equipment, dissatisfaction was sufficient by 1935 to lead to the purchase of automatic, solution-feed chlorinators. Before this equipment could be placed in operation, however, the plant was partially destroyed by the disastrous flood of 1935. Emergency chlorination was instituted, pending the rebuilding of the filtration plant. Unfortunately, conditions were such that the emergency chlorination, with a manually-controlled chlorinator, of the gravity supply flowing at unknown and varying rates led to the delivery of water having chlorinous tastes. As a result of this unfavorable situation, public sentiment again demanded the reconstruction of the plant with enlarged ozonating equipment. The filtration plant was reconstructed in 1936, but new ozonating equipment was never installed due to the financial failure of the Electrozone Corporation.

Itemized cost data for the new equipment are lacking. One new pressure filter unit 8 ft. by 16 ft. in size, new solution-feed equipment for alum and soda ash, and the rebuilding of the two old 12-tube ozone units and their duplication by two new units was to cost $7820. The completed ozone unit was to have a capacity of 168 grams of ozone per hour, or about 1 p.p.m. for 1.0 m.g.d. Independent cost data were secured from another company for their ozone equipment for the treatment of this volume of water but with twice the stated dose, or 2.0 p.p.m. The estimate was $20,000 for ozone equipment alone and $12 per day for current at a price of $0.02 per kilowatt-hour. The indications are that this larger unit would have been required to secure effective results at all times.

After a delay of two years, automatic chlorinators were installed in 1937 to replace the emergency, manually-controlled equipment which had been installed following the flood. In summary it may be stated that ozone treatment has several inherent advantages: (1) disinfection of water without the disinfectant itself imparting a taste; (2) effective oxidation of many taste-producing compounds, and (3) removal of some color by the bleaching action of the ozone. On the other hand, the disadvantages far outweigh these favorable factors: (1) the cost of complex ozonating equipment; (2) the difficulty for the average water works operator to understand and supervise such equipment; (3) the low solubility of ozone which is less than the concentration of residual ozone that should remain in the water for appreciable periods

of time; and (4) the lack of a satisfactory quantitative test for residual ozone that will permit accurate control of dosage.

Heavy Chlorination followed by Dechlorination with Granular Activated-Carbon at South Fallsburg, New York. There has been a revival of interest in superchlorination of water, that is, the use of chlorine doses so high as to require the use of dechlorinating agents. For this reason, the small water purification plant operated by the South Fallsburg Water Company at South Fallsburg, New York, may be of interest. Reference is made to the Journal of the American Water Works Association* for further description of this plant.

The resources of this water company were inadequate to enable it to install a gravity filtration plant that was needed for the adequate treatment of its polluted surface-water supply in which organic matter and algae had previously complicated treatment by chlorination alone. Accordingly, a compromise plant was installed to insure effective chlorination without the production of chlorinous tastes. The plant consisted of two pressure filters, 6½ ft. in diameter by 6 ft. high, equipment for feeding chlorine and alum to the raw water and soda ash to the filtered water, and a granular, activated-carbon unit consisting of a filter shell 6½ ft. in diameter by 9 ft. high housing a granular carbon bed 5 ft. deep. Nuchar of 4- to 30-mesh size was used. The unit was intended to remove from the filtered water tastes and odors as well as excess residual chlorine derived from heavy pre-chlorination. The sand filter was washed at a rate of 12 g.p.m. per sq. ft. and the carbon bed at one half this rate, the latter giving 50% expansion of the carbon.

The size of the units was such as to require a rate of 3 g.p.m. per square foot of sand filter and twice that value for the carbon unit. In the absence of adequate mixing and coagulating facilities, these rates were found to be excessive. On the other hand, effective disinfection was secured with proper operation, due to the fact that the doses of chlorine did not have to be reduced to dangerously low values in order to prevent chlorinous tastes. More effective filtration would have made it possible to produce a clear water and so to prolong the useful life of the carbon unit.

The raw water was dosed with from 1.5 to 6.0 p.p.m. of chlorine or sufficient to produce a residual of 0.5 p.p.m. in the filtered water flowing onto the carbon bed after a reaction period of 15 to 20 minutes. This residual was completely removed by the activated carbon, except recently when the carbon bed had become coated with foreign material and failed to reduce a residual of 1.0 p.p.m. to zero. In general, however, dechlorination has been complete even under unfavorable condi-

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TABLE 2—RESULTS OF ANALYSES OF SAMPLES COLLECTED AT SOUTH FALLSBURG WATER PURIFICATION PLANT, N. Y., BY J. E. KERSLAKE ON OCTOBER 9, 1936.

Sample No. (1)	Sampling Point (2)	Chlorine Dose lb. per m.g. (3)	Residual Chlorine p.p.m. (4)	Color p.p.m. (5)	Chloride p.p.m. (6)	Bacteria Per c.c. Agar 37°C. (7)	*B. coli* present in 10 c.c. (8)	*B. coli* present in 1 c.c. (9)	*B. coli* present in 0.1 c.c. (10)
1	Raw-water-pump discharge	None	None	35	3	950	5+0–	0+1–	0+1–
2	Prechlorinated water after 5-min. contact	52	1.9 to 2.6	32	6	3	0+5–	0+1–	0+1–
3	Effluent of sand filters	52	1.2 to 1.6	22	6	1	0+5–	0+1–	0+1–
4	Effluent of carbon filter	52	None	10	9	300	0+5–	0+1–	0+1–
5	Prechlorinated water after 5-min. contact	24.8	0.85	32	9	9	0+5–	0+1–	0+1–
6	Effluent of sand filters	24.8	0.45	28	9	4	0+5–	0+1–	0+1–
7	Effluent of carbon filter	24.8	None	15	7	900	0+5–	0+1–	0+1–
8	Prechlorinated water after 5-min. contact	15.6	0.4	32	8	7	0+5–	0+1–	0+1–
9	Effluent of sand filter	15.6	0.10 to 0.15	28	9	4	0+5–	0+1–	0+1–
10	Effluent of carbon filter	15.6	None	18	6	350	0+5–	0+1–	0+1–

tions. Effective chlorination, therefore, could be insured without the frequent change of chlorine dosage, to meet minor variations in chlorine demand, that is ordinarily required in order to maintain chlorine residuals within the narrow limits imposed by requirements of disinfection and freedom from chlorinous tastes. In fact, the chlorine residual of 0.5 p.p.m. was chosen in the interest of economy, because the maintenance of this residual simplified control and reduced the frequency of changing the dosage.

The results of examinations of samples collected at this plant on October 9, 1936, August 12, 1937 and August 17, 1939 are shown in Tables 2, 3 and 4. Briefly, these results indicate that failure properly

TABLE 3—RESULTS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED AT SOUTH FALLSBURG WATER PURIFICATION PLANT, N. Y., BY J. E. KERSLAKE ON OCTOBER 9, 1936.

(All values are p.p.m. except odor and pH)

Sample No.	1	6	7
Sampling Point	Raw-water-pump Discharge	Effluent of Sand Filters	Effluent of Carbon Filter
Color	35	27	18
Turbidity	3	Trace	Trace
Odor			
Hot	1 aromatic	2 aromatic	3 aromatic
Cold	1 aromatic	2 aromatic	3 aromatic
Total iron	0.4	0.2	0.13
Manganese	0.04	0.04	0.01
Oxygen consumed	3.1	3.4	1.1
Hardness	18	18	18
Alkalinity	14	10	7
pH value	6.9	6.3	6.1

Alum dose applied to pump suction—62 lb. per m.g.

to coagulate the raw water and to wash the filters and the carbon unit had resulted in the passage of taste-producing compounds through the carbon unit by October 9, 1936 after the plant had been in operation for only two months. Treatment, however, reduced turbidity from 3.0 p.p.m. to a trace, color from 35.0 to 18.0 p.p.m. and oxygen consumed values from 3.1 to 1.1 p.p.m. Pre-chlorination with doses of 15.6 to 52 lb. per m.g. produced chlorine residuals in the sand-filter effluent between 0.10 and 1.6 p.p.m., with no residual in the effluent of the carbon unit. Effective bacterial removal was secured with the lowest dose noted, but the raw water at the time was only moderately polluted.

TABLE 4—RESULTS OF ANALYSES OF SAMPLES COLLECTED AT SOUTH FALLSBURG, N. Y., BY J. E. KERSLAKE ON AUGUST 13, 1937.

	Raw-water Intake, Sheldrake Creek	No. 11 Plant Effluent at Outlet of Carbon Filter	Tap at Gulf Gas Station
Color	45	9	9
Odor			
hot	4 aromatic	3 aromatic	2 aromatic
cold	1 aromatic	1 aromatic	1 aromatic
Turbidity	Trace	Trace	Trace
Iron	0.4	0.1	0.06
Manganese	0.01	0.01	0.01
Nitrogen as:			
Free Ammonia	0.222	0.056	0.041
Albuminoid Ammonia	0.228	0.096	0.080
Nitrites	0.08	0.001	0.002
Nitrates	1.40	1.60	1.20
Oxygen consumed	7.6	3.4	3.8
Chlorides	6.4	8.0	7.8
Hardness	18.0	28.0	28.0
Alkalinity	19.0	7.0	9.0
pH value	6.7	6.7	6.1
Bacteria per cc. 37°C.	51,000	1,900	55
Test for *B. Coli*			
Group in:			
10 c.c.	5+0–	0+5–	0+5–
1 c.c.	1+0–	0+1–	0+1–
1/10 c.c.	1+0–	0+1–	0+1–
1/100 c.c.	1+0–	—	—

Chemical results are expressed in parts per million.

\+ *B. coli* present.

– *B. coli* absent.

2+1– *B. coli* present in 2 and absent in 1 of 3 volumes tested.

Microscopical Examination of Raw-water Intake, Sheldrake Creek

Organisms	Standard Units per c.c.
Diatoms	
Synedra	46
Navicula	16
Chlorophyceae	
Scenedesmus	8
Cyanophyceae	
Chroöcoccus	30
Aphanocapsa	16
Protozoa	
Mallomonas	54
Unidentified	
Schizomycetes	860
Amorphous Matter	600

TABLE 5—RESULTS OF BACTERIOLOGICAL EXAMINATIONS OF SAMPLES COLLECTED AT SOUTH FALLSBURG, N. Y. (SPECIAL INVESTIGATION TO DETERMINE CAUSE OF POOR BACTERIOLOGICAL RESULTS)

Sample No.	Date Collected	Time Collected	Source	Alum lb. per m.g.	Soda Ash lb. per m.g.	Chlorine lb. per m.g.	Res. Cl. p.p.m.	Taste	Bacteria per c.c. Agar 37°C.	Tests for *B. Coli* Group in: 10 c.c.	1 c.c.	0.1 c.c.	0.01 c.c.
1	8-12-37	2 P.M.	Raw-water intake	—	—	—	—	—	92,000	5+0–	1+0–	0+1–	0+1–
2	8-12-37	2 P.M.	To Carbon Filter	30	None	25	0.45	Weedy, Cl.	700	0+5–	0+1–	0+1–	—
3	8-12-37	2 P.M.	From Carb. Filter	30	None	25	None	Weedy, Cl.	240,000	5+0–	1+0–	0+1–	—
4	8-12-37	3 P.M.	To Carbon Filter	30	None	30	0.8	Weedy, Cl.	1,200	0+5–	0+1–	0+1–	—
5	8-12-37	3 P.M.	From Carb. Filter	30	None	30	None	Weedy	110,000	4+1–	0+1–	0+1–	—
6	8-13-37	10:40 A.M.	Raw-water intake	—	None	—	—	—	51,000	5+0–	1+0–	1+0–	1+0–
7	8-13-37	10:30 A.M.	To Carbon Filter	None	None	25	0.5	Weedy, Cl.	250	0+5–	0+1–	0+1–	—
8	8-13-37	10:30 A.M.	From Carb. Filter	None	None	25	None	Weedy	4,400	0+5–	0+1–	0+1–	—
9*	8-13-37	10 A.M.	From Carb. Filter	None	None	30	*None	Weedy	200	5+0–	0+1–	0+1–	—
10	8-13-37	11:15 A.M.	To Carbon Filter	75	100	25	0.43	Weedy, Cl.	2	0+5–	0+1–	0+1–	—
11	8-13-37	11:15 A.M.	From Carb. Filter	75	100	25	None	Weedy	1,900	0+5–	0+1–	0+1–	—
12	8-13-37	12 Noon	To Carbon Filter	75	100	30	0.75	Weedy, Cl.	5	0+5–	0+1–	0+1–	—
13	8-13-37	12 Noon	From Carb. Filter	75	100	30	None	Weedy	39	0+5–	0+1–	0+1–	—
14	8-13-37	11:30 A.M.	Tap	—	—	—	None	Weedy	55	0+5–	0+1–	0+1–	—

* Residual chlorine content at inlet to carbon filter 0.85 p.p.m.

NOTES: Thio-sulphate sample bottles were used to collect all samples containing residual chlorine.
Samples 2 to 5 inclusive, alum applied at beginning of each day when starting pump.
All filters were washed at 6 A.M. on August 13, 1937. No alum or soda ash was used when pump was started.
Pumping rate 200 g.p.m. (filter rate 3 g.p.m. per sq. ft. of sand filter, 6 g.p.m. per sq. ft. of carbon unit).

No great improvement in operation was noted on August 12 and 13, 1937, as shown in Table 5, but the much greater content of organic matter and degree of pollution of the raw water led to greater percentage removal of color, oxygen consumed values and bacteria. Notwithstanding poor coagulation control, heavy pre-chlorination was completely effective in bacterial removal.

Table 6 indicates that the same general conditions prevailed on August 17, 1939. Taste removal, however, was entirely effective, notwithstanding the fact that the filter influent was not being co-

TABLE 6—RESULTS OF EXAMINATIONS OF SAMPLES OF WATER COLLECTED FROM SOUTH FALLSBURG WATER FILTRATION PLANT ON AUGUST 17, 1939.

Chemical Analyses

		Chlorine Dose 30 lb. per m.g.		Chlorine Dose 48 lb. per m.g.	
	Raw water	Sand filter effluent	Carbon filter effluent	Sand filter effluent	Carbon filter effluent
Color	45	28	28	26	28
Turbidity	10	trace	trace	trace	trace
Odor, cold	3 disagreeable	3 chlorine	1 earthy	3 chlorine	2 aromatic
Taste		2 tart earthy	1 earthy	2 earthy	none
Total iron	1.7	0.5	0.47		
Chlorine demand	1.10		0.21		0.26
Free ammonia nitrogen	0.020	0.036	0.022		
Albuminoid ammonia nitrogen	0.646	0.596	0.596		
Nitrite nitrogen	0.02	<0.001	<0.001		
Nitrate nitrogen	0.9	0.9	1.0		
Oxygen consumed	10.2	8.6	7.5	8.0	8.0
Chlorides	5.8	8.8	9.2		
Total hardness	24.0	22.0	16.0		
Alkalinity	15.0	11.0	10.0		
pH	6.9	6.7	6.8	6.3	6.7
Chlorine residual	0	0.6	0	1.0	0

Chemical results are expressed in p.p.m.

Bacterial Analyses

Bacteria per ml., 24 hr. at 37°C.	22,000	40	26	17	12
Coliform group M.P.N. per 100 ml.	2,400	<2.2	<2.2	<2.2	<2.2

No alum or soda ash were applied.

M.P.N.=Most probable number.

agulated, because the demand for water would have exceeded the filter capacity with the filters coated with alum floc.

This surface water supply and partially successful treatment plant will be replaced in the near future by a new well supply that is being developed by the South Fallsburg Water District.

In summary, the following statements regarding the South Fallsburg plant are pertinent:

1. That failure effectively to coagulate and remove suspended solids, organic matter and taste-producing compounds is due primarily to faulty operation, lack of mixing and coagulation basins, and excessive rates of operation.

2. That notwithstanding these defects, heavy pre-chlorination followed by dechlorination through carbon units provided means for effectively disinfecting, with short reaction periods and without the production of chlorinous tastes, polluted water, containing large concentrations of organic matter.

3. That the effectiveness of chlorination does not depend upon varying the chlorine dosage to meet moderate changes in chlorine demand of the raw water but on the use of concentrations sufficiently heavy to meet maximum requirements and thus to insure consistent and reliable results without close technical supervision.

4. That granular carbon beds will remove residual chlorine from water long after they have lost their power to adsorb taste and odor-producing compounds, due to the fact that chlorine is not removed by adsorption but directly reacts with the carbon.

Softening of a very hard water at Elba, New York. The village of Elba, Genesee County, New York, installed a water supply system in 1935. Soft surface water was not available, so it was necessary to develop two wells drilled into gypsum rock which yield water of very high hardness, namely 1100 to 1500 p.p.m. Although the softening of water of this character by the zeolite process was not advocated by the designing engineers nor by the manufacturers of zeolites, no alternative was practicable, and a zeolite plant having a capacity of about 100 g.p.m. was installed. The zeolite unit was 6 ft. in diameter and 8 ft. high.

Originally, one well was equipped with a motor-driven deep-well pump, whereas another well was equipped with an air lift. Water was forced from both wells to the softening unit, and the softened water was pumped from a concrete basin into the distribution system by a high-lift pump.

It was soon found that the results secured depended upon which

well was being utilized. When the motor-driven deep-well pump was in use, the iron remained in a reduced state, and very complete removal was secured by the base-exchange process without clogging the zeolite bed. The water produced under these circumstances was only moderately corrosive due to the absence of oxygen. On the other hand, odors due to hydrogen-sulphide appeared during the summer months in the water drawn from the distribution system, although the plant effluent was odorless. This was proved to be due to the biochemical reduction of sulphates to sulphides in the absence of oxygen.

Conversely, when the air-lift unit was in use, the iron in the well water was oxidized, and precipitated iron accumulated in the zeolite bed. This precipitate was not all removed when the beds were regenerated and washed. The effluent contained oxygen and was more corrosive, but odors of hydrogen sulphide were less noticeable.

Table 7 illustrates conditions that obtained when both wells were

TABLE 7—RESULTS OF ANALYSES OF SAMPLES COLLECTED AT THE ELBA, N. Y., WATER SOFTENING PLANT, BY R. D. BATES ON SEPTEMBER 4, 1935

	Well No. 2	Softener effluent	Tap on system
Color	5	0	5
Odor, hot	1 aromatic	1 aromatic	3 aromatic
Odor, cold	1 aromatic	1 aromatic	3 aromatic
Turbidity	1	trace	69
Iron	0.6	0.1	4.7
Sulfate	900.0	900.0	900.0
Nitrogen as:			
Free Ammonia	0.012	0.008	0.002
Albuminoid Ammonia	0.058	0.042	0.038
Nitrites	0.004	0.003	0.007
Nitrates	0.02	0.02	0.02
Oxygen consumed	0.9	1.0	2.5
Chlorides	26.0	27.0	28.0
Hardness, total	1220.0	54.0	146.0
Alkalinity	225.0	220.0	225.0
pH	7.1	7.1	7.1

Chemical results are expressed in parts per million.

used alternately and when odor difficulties and corrosion were a serious problem. This is illustrated by the marked increase in intensity of odor when the water passed through the system and by the increase in iron content from 0.1 p.p.m. in the effluent to 4.7 p.p.m. in the delivered water. The benefits secured from the use of the air-lift unit in reducing

odor difficulties were counteracted by an increase in corrosiveness of the water and by an increase in the iron content of the zeolite bed.

These difficulties were solved by the installation of a coke aerator between the zeolite unit and the high-lift pump. In this way, the deep-well pump forced unaerated water through the softening unit, thereby securing softening and iron removal by the base-exchange process. The softened water was then aerated to prevent biological reduction, and caustic soda and sodium silicate were added to prevent corrosion.

Table 8 illustrates the conditions that prevailed with this improved treatment.

TABLE 8—RESULTS OF ANALYSES OF SAMPLES COLLECTED AT THE ELBA, N. Y., WATER SOFTENING PLANT BY F. D. ZOLLNER ON JUNE 12, 1939.

	Drilled well	Treated water	Tap near end of line
Color	12	0	0
Odor, hot	1 vegetable	1 vegetable	1 vegetable
Odor, cold	1 vegetable	1 vegetable	1 vegetable
Turbidity	10	trace	trace
Iron	0.7	0.17	0.2
Solids, total	2058.0	1964.0	1993.0
Loss on ignition	285.0	46.0	45.0
Mineral residue	1773.0	1918.0	1948.0
Nitrates	—	0.02	0.02
Soda Reagent Hardness, total	1410.0	36.0	40.0
Chlorides	14.0	27.0	27.0
Alkalinity	227.0	218.0	227.0
pH value	7.1	7.9	8.5
Non-carbonate hardness	1160.0	0	0

Chemical results are expressed in parts per million.

A review of Table 8 illustrates that the raw water having a total hardness of about 1400 p.p.m. was softened to a hardness of about 40 p.p.m., no raw water being bypassed around the softener. The total mineral content of the water naturally remained very high: about 1900 p.p.m., of which sulphates account for 1,000 to 1,200 p.p.m. This mineral residue imparts laxative properties to the water which are noticeable to strangers but not to residents of the village. In fact the residents were accustomed to drinking excessively mineralized water from neighborhood wells before the public supply was developed.

The final alkalinity of the effluent is about 225 p.p.m., and the pH value is about 7.1 p.p.m. before aeration and alkali treatment. These

values are very close to those obtaining at calcium carbonate equilibrium; nevertheless, the water is corrosive. This experience is consistent with other data that indicate that zeolite-softened water is more corrosive than would appear from the alkalinity and pH of the water. The application of 6 p.p.m. of caustic soda and 6 p.p.m. of sodium silicate, however, to increase the pH value to the zone between 7.8 and 8.5 is effective in preventing corrosion in the distribution system, insofar as this is indicated by the iron content of water drawn from the system.

In summary, the situation at Elba indicates the complex relationship of many factors that must be considered in the design and operation of plants treating unusual waters.

Summary. In conclusion it may be stated that the experience at Delhi demonstrates the necessity that water-purification equipment be developed by engineers experienced in the treatment of public water supplies and that newly-developed apparatus be subjected to thorough testing under full-scale operating conditions before it is sold to the public.

The experience at South Fallsburg illustrates that little can be gained by providing inadequate water purification equipment because of financial limitations, especially in the absence of a trained operator who might use his resourcefulness to offset some of the limitations of equipment.

The experience at Elba demonstrates the complexity of the treatment of unusual waters and the necessity for making adequate laboratory investigations in order to provide the basis of design.

As might be gathered from this discussion, it was not possible for the New York State Department of Health to insist upon the construction of specific types of water treatment plants at Delhi and South Fallsburg as long as the proposed plants were considered reasonably satisfactory *from a public health standpoint.* Every effort was made, however, to have Delhi install a conventional gravity filtration plant with disinfection by chlorination, and for the South Fallsburg Water Company to install a treatment plant of larger capacity. Subsequent developments clearly demonstrated the wisdom of such recommendations.

COMBATING BACKFLOW IN WATER SUPPLY SYSTEMS

BY R. H. ZINKIL*

[*Read September 14, 1939*]

General interest in backflow hazards appears to be increasing, although it has been slow in developing the momentum its importance warrants. Experience in committee work and code activities has demonstrated that confusion and misunderstanding can be reduced by defining and explaining the important terms to be used. Therefore, for the purpose of making this paper as clear as possible, the following list of definitions and explanations (taken from Proposed American Standards, which will be mentioned later) is given.

Backflow means the flow of impure (non-potable) water into a pure (potable) water system. The flow may be caused by gravity, vacuum, or other pressure differential.

Backflow Connection is any arrangement whereby backflow can occur.

Air Gap in a water supply system for plumbing fixtures is considered as the vertical distance between the supply fitting outlet (spout) and the highest possible water level in the receptor (when flooded). The air gap (see "A" in Fig. 3), required to prevent backflow through a water supply opening (faucet or valve) under the action of atmospheric pressure and a vacuum in the water supply system, depends principally on the effective opening, as defined in the following paragraph.

Effective Opening (see "B" in Fig. 3) is the minimum cross-sectional area between the end of the supply fixture outlet (spout) and the inlet to the controlling valve or faucet (See "X" in Fig. 3). The basis of measurement is the diameter of a circle of equal cross-sectional area. If two or more lines supply one outlet, the effective opening is the sum of the effective openings of the individual lines, or the effective opening of the combined outlet, whichever is the smaller.

Safe Air Gap is any gap greater than the maximum gap across which backflow can occur under any condition of service.

Backsiphonage is one form of backflow caused by a vacuum in the water supply pipes.

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Backsiphonage Preventer (sometimes called vacuum breaker) is a device for installation in a water supply pipe to prevent backsiphonage of water into the water supply system from the connections on its outlet end.

Air Valve of a backsiphonage preventer is the valve that restricts or controls the rate of airflow when a vacuum exists in the water supply system (See Fig. 1).

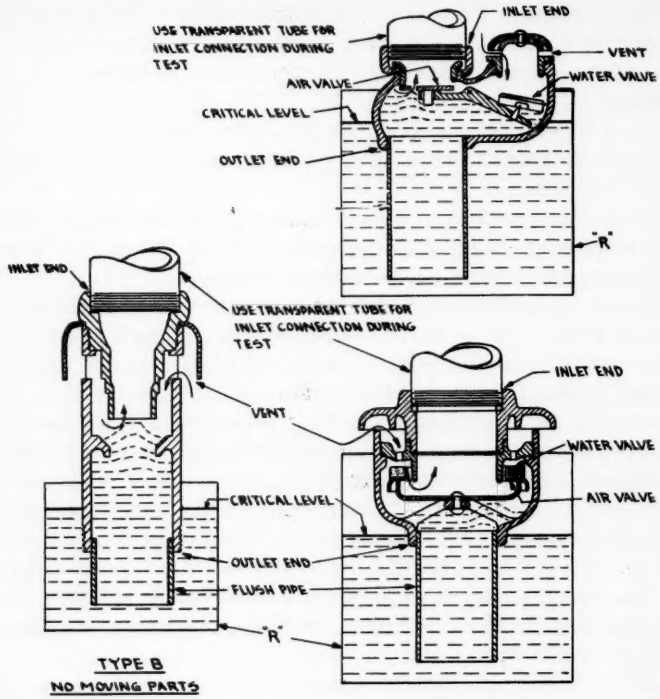
Vent (air inlet) of a backsiphonage preventer is a passage or series of passages leading through the body of the device from the surrounding atmosphere to the water passage.

Water Valve of a backsiphonage preventer is the valve that closes the vent when water is flowing to the fixture and prevents outflow of water from the vent (See Fig. 1). Some designs are such that the same disc unit is used for both the water valve and air valve.

Critical Level of a backsiphonage preventer, when a vacuum of 15 in. of mercury or greater exists in the supply line to the fixture, is the highest horizontal plane through the preventer at which the preventer can be immersed in water, open to the atmosphere, before siphonage begins through the preventer. Conversely, the critical level may be defined as the highest horizontal plane to which the flood level of a fixture can be raised relative to a backsiphonage preventer before siphonage begins, when a vacuum of 15 in. of mercury exists in the supply line (See Figs. 1 and 2).

Flood Level is the highest horizontal plane to which water can rise in a plumbing fixture or receptacle (usually the rim) before water will overflow onto the floor. Connections below rim which are called "overflows", to carry water from a certain level to the waste or soil pipes, are *not* recognized as *flood level,* except under special conditions, for example:

1. A tank or vat fitted with overflow connections and piping of sufficient capacity to keep the water level below the critical level of a backsiphonage preventer, if one is used, or below the end of the supply spout or nozzle that has the required safe air gap elevation for the piping involved—when water is entering the tank at the maximum rate of flow. In such cases, the top of the overflow opening in the tank is rated as flood level, providing there is a safe air gap break in the overflow piping as close to the tank as possible, to allow overflow water to spill onto the floor in case the waste pipe line becomes clogged.
2. A closet tank, because the overflow water from it runs down into the closet, and if the soil pipe is stopped, the water will overflow from the closet rim onto the floor. Therefore, the top of the overflow opening is rated as flood level, providing the edge at the top end of the wall is well rounded (not cut square) and the overflow channel has an internal area not less than 0.78 sq. in. (1 in. in diameter) at all points.



TYPES OF BACK-SIPHONAGE PREVENTERS

SEE SPECIFICATION UNDER "CRITICAL LEVEL TESTS" FOR OUTLINE OF TESTS TO LOCATE CRITICAL LEVEL

Outlet End of Backsiphonage Preventer is the end where the pipe connection is made to carry the discharge from the backsiphonage preventer.

Water Lift of a backsiphonage preventer is the maximum rise of water (in inches) in the flush pipe (a) when its open end is immersed in water open to atmospheric pressure; (b) when a vacuum of 15 in. of mercury, or greater, exists on the supply side of the preventer; and (c) when the critical level is 4 in. above the water level.

Control Valve is the valve that is operated each time water is supplied to, or shut off from, a receptacle or plumbing fixture.

Direct Flushing Valve is a self-closing type of valve primarily used to supply water direct from a water supply pipe to flush a water closet, urinal, etc. It is one type of control valve.

General Outline of Problem. As there has been a great deal of oral and written discussion as to the cause and effect of backflow, this paper has been prepared on the assumption that the reader is acquainted with backflow problems in water systems and that he realizes the following:

(1) Backflow, due to vacuum, can occur with different types of fixtures and water piping systems, unless preventive means are employed.
(2) The probable frequency of vacuum backflow conditions at different points varies and depends: (a) on pipe size proportions; (b) on frequency of high flow rate, i.e., discharge; and (c) on loss of pressure in water main or supply piping, such as is caused by a fractured pipe or heavy demands by fire-department pumps, etc.
(3) Backflow from any source in a water supply piping system may pollute the water delivered to any other fixture connected to the same supply piping.
(4) Backflow from any water supply piping system through the service pipe into the water main may pollute the water delivered to any other building supplied from the same water main.
(5) Backflow can occur when water of questionable purity from some source other than the regular water mains is allowed, at times, to flow through the same pipes which normally carry the pure water from the mains. No such auxiliary supplies ever should be connected to regular pure water supply piping.

Preventive Means. Two means of preventing backflow have been recognized: (a) safe air gaps, and (b) backsiphonage preventers. Unfortunately no nationally accepted standard for these means exists. However, health and plumbing authorities in many cities and states now realize the need for codes that will require installations of piping and fixtures that will be proof against backflow into water supply systems. It is also recognized that there is a need for a uniform national specification for the construction, operation, and testing of devices designed to prevent backflow. In recognition of the need for such a uniform specification, several organizations have enlisted the support of the American Standards Association, which formed Sectional Committee A40. This committee has been at work for some months. The specifications that this committee may finally develop will, of course, govern the effectiveness to be obtained. For this reason, it is important to direct attention to some of the matter being considered by the A.S.A. committees.

Air Gaps. The following data for air gaps have been approved

by Sub-Committee 12 of A.S.A Sectional Committee A40.[1] These data are considered as a proposed standard until approved by Sectional Committee A40 and A.S.A. officials.

In order to avoid complicated measurements and tests, to simplify specifications and inspection, and to allow a reasonable tolerance in inspection measurements, it is recommended that air gaps in common plumbing fixtures be as follows:

TABLE 1—RECOMMENDED AIR GAPS FOR COMMON PLUMBING FIXTURES**

Fixture and Fitting	Diameter of Effective Opening Not Greater Than	Minimum Air Gaps
Lavatories	0.50 in.	1 in.
Sinks, Laundry Trays and Gooseneck Bath Faucets	0.75 in.	1½ in.
Overrim Bath Fillers	1.00 in.	2 in.

**NOTE: If the effective opening is greater than specified in Table 1, the minimum air gap shall be equal to twice the diameter of the effective opening.

The minimum air gaps recommended in Table 1 and its footnote apply when no wall extending to or above the level of the spout opening is close to the supply outlet. If any vertical wall extending to or above the horizontal plane of the spout opening is closer to the nearest inside wall of the supply opening than four times the diameter of the effective opening, the air gap shall be at least three times the diameter of the effective opening, but, in no case, less than the air gap specified in Table 1 (See "C", Fig. 3). Should the plane of the end of the spout be at an angle to the surface of the water, the mean gap is to be the basis for measurement (See Fig. 3).

Backsiphonage Preventers. The following specifiations for backsiphonage preventers have been approved by a Technical Sub-Group of Sub-Committee 12 of A.S.A. Sectional Committee A40. These are considered as a proposed standard until approved by Sectional Committee A40 and A.S.A. officials.

This standard applies to the performance characteristics, and to the essential construction on which the required performance depends, of backsiphonage preventers for use with direct-flushing valves and under-rim water supply connections to a plumbing fixture or receptacle

[1]The technical sub-group that developed this proposed standard consisted of Messrs. A. B. Cronkright, F. M. Dawson, R. B. Hunter, E. Sohn, and R. H. Zinkil (chairman).

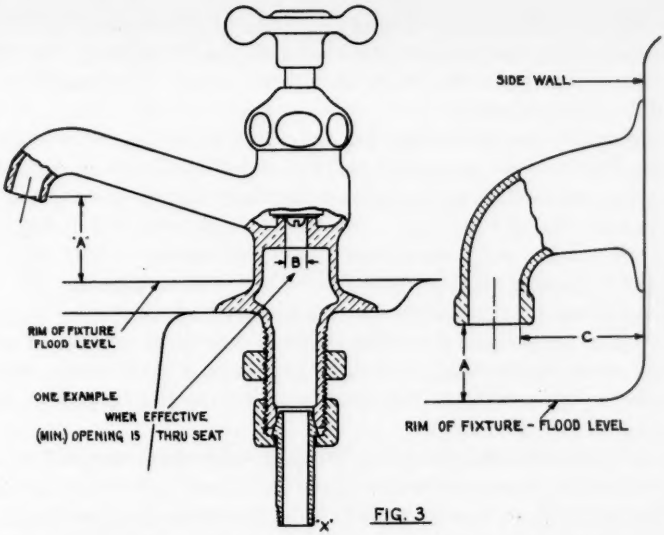


FIG. 3

in which the surface of the water in the fixture or receptacle is exposed at all times to atmospheric pressure. Two types of backsiphonage preventers are included:

Type A backsiphonage preventers whose performance in preventing backflow depends on the automatic mechanical operation of one or more moving or movable parts wholly within the device (See. Fig. 1); and

Type B backsiphonage preventers whose performance in preventing backflow does not in any way depend on the operation of a moving or movable part or parts (See Fig. 2).

The backsiphonage preventer shall be a complete working unit that possesses (a) a water passage or channel of sufficient size and proportions to allow an ample flow of water to the fixture or receptacle with which it is installed; (b) an air vent leading from the water passage to the surrounding atmosphere; and (c) suitable means for connecting the preventer to the water supply line.

The backsiphonage preventer unit may be contained in the body or casting of the control valve, or it may be a separate unit installed between the control valve and the fixture. The lower end of the backsiphonage preventer body shall be below the critical level.

The backsiphonage preventer shall prevent backflow of water through it from the fixture or receptacle with which it is installed under

all possible conditions of filling or flooding of the fixture and under all conditions of pressure or vacuum that can or may occur in the water supply system. Furthermore, it should not cause objectionable noise due to injection of air.

Type "A" backsiphonage preventers with moving parts shall include a disc or other movable unit that will normally be in a position to prevent the force of the vacuum in the water supply line from acting on the contents of the water closet or other fixture that it supplies, when the water is not flowing from the control valve. Under this condition the air ports shall be open full. When water flows, the disc unit shall be moved by the water and close the vents or air ports. The disc shall return to its normal position without help from springs or other flexible or elastic materials as soon as the water stops flowing. It must complete a cycle of these movements each time the control valve is opened and closed.

Moving parts shall be loose fitting movable discs or rings with or without levers, or a combination of parts that act essentially as a unit. In this standard, such a device is called a movable unit (See Fig. 1).

The backsiphonage preventer shall be so installed between the control valve and the fixture that it will not be subjected to water pressure, except the back pressure when water is flowing to the fixture. Each backsiphonage preventer shall bear the manufacturer's name or trademark plainly cast or stamped on the body, and such other permanent marking as may be necessary to identify it from any other model or design that is, or has been made by the manufacturer. It shall have the location of the critical level plainly cast or stamped on the body and designated by one of the following symbols: C $\underline{\qquad}$ L or $\frac{C}{L}$, the horizontal line of the symbol designating the critical level.

To determine the critical level of a backsiphonage preventer place it in a receptor, "R", as shown in Figs. 1 and 2. Then: (1)[2] (a) supply water to receptor slowly through submerged inlet (such as hose) to keep surface level as calm as possible; (b) maintain a vacuum of at least 15 in. of mercury in the piping connected to the backsiphonage preventer inlet while water level is rising in receptor; (c) watch carefully for backflow; and (d) as soon as backflow occurs, make a temporary mark on the outside of the body to show location of water level.

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[2] *Alternate Method*: The critical level may be determined by starting with the water level in the receptor, "R", high enough to cause backflow, and then siphoning the water out until backflow ceases. From this point, proceed as in (e), (f), and (g).

After this proceed as follows: (2) (e) when backflow first occurs (1-d) close valve in supply line, thus destroying the vacuum; (f) drop water level in receptor 1/16 in.; and (g) test at 15 in. of mercury vacuum by quickly opening valve (quick-open type) in the supply line. If backflow occurs, repeat the test as many times as necessary by dropping the water level in the receptor 1/16 in. for each test until backflow does not occur. The water level so determined is the *critical level*, and is to be so marked. The preventer is to be *rejected* if the *critical level* so determined *is below the lower end of its body.*

Backsiphonage Preventers for Direct Flushing Valves. The critical level of a backsiphonage preventer body shall be installed at least 4[3] in. above the flood level of the fixture. If the backsiphonage preventer is not marked to show critical level, the installation elevation shall be measured from the lower end of the backsiphonage preventer body.

A backsiphonage preventer for use on the outlet end of a direct flushing valve must be of such construction, size, and proportion, and with such suitable air ports, as *to prevent a water rise of more than one inch* in the outlet end which leads to the fixture.

The following test procedure shall be followed: (a) Attach the backsiphonage preventer to the outlet end of a direct flushing valve in which the plunger unit or diaphragm is held wide open or has been removed; (b) connect a transparent flush pipe to the outlet end of the backsiphonage preventer, and immerse the end in water (water level to be 4 in. below the outlet end of the backsiphonage preventer) in an open vessel, or a water manometer may be used, and a vacuum applied through the flush valve; and locate (c) the vacuum gauge not more than 3 ft. from the backsiphonage preventer, and run pipe not less than 1 in. in diameter from the gauge connection to the device being tested.

Three types of tests are to be made:

Test A. Test for at least 30 seconds under a sustained vacuum pressure of less than ½ standard atmosphere (approximately 15 in. of mercury).

Test B. Starting with atmospheric pressure in the supply connection to the flush valve, reduce the pressure to a vacuum of at least 15 in. of mercury *in not over 5 seconds.*

Test C. Same as test B, except pressure reduced to a vacuum of at least 15 in. of mercury *in not less than 5 minutes.*

It should be noted that the values of time in tests A, B, and C,

[3]In special cases where a backsiphonage preventer is being added to an old installation, and 4 in. of elevation, as specified, are not available, 2 in. are considered a minimum.

namely 30 seconds, 5 seconds, and 5 minutes, are limits in one direction only, and that any device under test may be subjected to a more rapid reduction of pressure for test B, and be under maximum vacuum conditions for a longer time than that stated for test A and test C.

Backsiphonage Preventers for Fixtures with Submerged Inlets and Open to Atmospheric Pressure—Other Than Direct Flushing Valves. The same specifications and tests apply to backsiphonage preventers for fixtures with submerged inlets—other than direct flushing valves—as apply for backsiphonage preventers with direct flushing valves as previously outlined, except that the critical level or lower end of the backsiphonage preventer body shall be installed as high as practical for each installation, but never less than 4 in. above the flood level of the fixture. Sizes larger than 1 in. shall be elevated, not less than 4 times the effective opening. In order to emphasize the importance of proper installation: "The backsiphonage preventer must be on the outlet end of the control valve so that it will not be subjected to water pressure unless the control valve is open."

Backsiphonage Preventers for Ball Cocks or Float Valves for Tanks Open to Atmospheric Pressure Which Normally Contain Pure Water. Ball cocks or float valves for controlling water supply to open tanks shall be equipped with satisfactory backsiphonage preventers, or else discharge water above the overflow opening in the tank. The critical level, when a backsiphonage preventer is used—or the outlet end and the refill tube connection, when no backsiphonage preventer is used—shall be 1 in. or more above the overflow opening in the tank. This elevation is based on an effective opening of not more than ½-in. diameter through the ball cock. If the effective opening is greater, the elevation above the overflow opening shall be not less than twice the effective opening. The edge at the top end of the overflow wall shall be well rounded (not cut square), and the overflow channel shall have an internal area not less than 0.78 sq. in. (1 in. in diameter) at all points.

A ball cock or float valve shall prevent water in the tank from flowing back into the supply pipe, by gravity, from any level up to 1 in. above the overflow opening in the tank. In view of the importance of the relative position of the ball cock, backsiphonage preventer, and overflow opening in the tank, a complete tank with all trimmings shall be used for tests.

Ball-cock or float-valve tests shall be the same as required for backsiphonage preventers used with direct flushing valves, and for

critical level, and in addition: the ball-cock plunger or diaphragm shall be held wide open during the entire test, and the tank filled with water to the overflow opening. (Submerging the float does not always hold open sufficient for test.) Furthermore, during the entire test the water passages shall be completely unobstructed, *i.e.*, all control valves shall be set or held wide open, and any other restrictions made of flexible or elastic materials, such as leather or rubber washers, cup leathers, diaphragms, etc., whose characteristics may vary with age or under different water conditions, and thereby change their influence on backflow resistance, shall be removed.

The end of the refill tube shall be submerged, and any refill control means shall be wide open.

The water level in the tank shall be 1 in. below the critical level, or outlet end of the ball cock or backsiphonage preventer, if one is used, and if the *water level in the hush tube or refill tube rises more than ½ in. the device is not satisfactory.*

For larger float valves that are equipped with backsiphonage preventers, other than those used to fill closet tanks, a water rise not greater than the diameter of the effective opening is allowable, and the water level in tanks shall be at a distance equal to twice the effective opening, below the critical level or outlet end.

These test requirements apply whether a backsiphonage preventer is used or not.

Application of Preventive Means. In the light of the provisions of the proposed uniform specification let us consider what they mean in protecting pure water from backflow pollution. There are two conditions to be considered: (1) protection of the pure water in the water mains; and (2) protection of the water in the supply piping systems of buildings.

The water in the mains can be protected against backflow from the piping in a building by running the service pipe direct from the main to a point over an open tank, with a safe air gap between the outlet end of the supply nozzle and the flood level point of the tank. *Positively no other branch tappings should be run from this service pipe.* The discharge piping from the tank should be used only to supply water to fixtures, and at no point should it be connected to the service pipe running from the water main to the tank.

Some have suggested the use of a "looped" service pipe, elevated more than 34 ft. vertically from the highest branch supply pipe or fixture-spout that is connected to the downleg. It is claimed that such

a loop would prevent backflow from the supply piping system through the service pipe to the water main. The best loop of this kind would not provide the same degree of protection as a safe air gap. Furthermore, a loop of correct size and elevation would present a difficult installation problem.

In many installations the "service pipe air gap system" is not practicable. In such cases it becomes necessary to protect the water in the mains indirectly by protecting the water in the supply piping systems in the buildings. This is done by specifying that *each fixture* shall have a safe air gap, or that *each fixture* shall be provided with approved backsiphonage preventers. Protection against backflow *at each fixture or point where water discharges* from supply piping, is of major importance: (1) because other fixtures connected to the same supply piping system are protected thereby; and (2) because added protection is provided for the water main which indirectly protects other buildings that are supplied by the same water main.

At the present time we do not know of any satisfactory means of protecting a whole system, or group of fixtures in any other manner than individually.

Drinking Fountain Bubblers. To state that it is extremely important to prevent backflow through a drinking fountain bubbler undoubtedly would meet with general approval. However, no standards for bubbler elevation that are based on test results or generally accepted data have been developed, to our knowledge.

Experiments with backflow, caused by vacuum through supply spouts, pipes, etc., all of which had ends above the water level, were extremely interesting and produced some surprising results. In these cases the water flowed in a downward direction under normal conditions, and air flowed in an upward direction in case of vacuum. In the case of drinking fountain bubblers, the flow of water and air was the reverse of that of spouts; that is, the water flowed in an upward direction through the bubbler orifice under normal conditions and the air flowed downward in case of a vacuum. The water creeps upward towards the bubbler orifice, under vacuum, because usually the bubbler shank or some connecting member projects through the surface of the water when the receptor is flooded, thereby supplying a means for the water to flow back into the bubbler orifice.

New Data and Recommendations

In addition to the proposed uniform specification that we have been

considering, I wish to call to your special attention some additional data and recommendations. We believe these data are new. Our recommendations are based upon actual experimental tests. These data and recommendations were evolved in an effort to solve the problem of determining *how high the lower edge of a bubbler orifice should be placed above the flood level of a receptor to be safe against backflow when a vacuum sufficient to cause a critical pressure condition existed in the water supply pipe.*

The experimental work was done with three different types of bubblers and some plain tubes, as follows:

1. A single round orifice (with guard), 0.300 in. in diameter.
2. Three small round orifies (no guard), each 0.199 in. in diameter.
3. A long narrow slotted orifice (with guard), 0.860 in. by 0.083 in.
4. Plain tubes 2 in. long. Ends of tubes filed square and exterior cylindrical surfaces buffed. Vertical and at 30 degrees from the vertical. Tubes set at 30 degree angle also were tested with flat plates approximately 3 in. in diameter mounted flush with end of tube: (a) 0.181 in. in inside diameter; (b) 0.233 in. in inside diameter; and (c) 0.421 in. in inside diameter.

Results in Table 2 show the minimum elevation at which backflow did not occur.

TABLE 2—MINIMUM ELEVATION AT WHICH BACKFLOW DID NOT OCCUR.
(Distance Measured From Lower Edge of Orifice to Water Surface)

Bubbler	1	2	3	Tube 4a	Tube 4b	Tube 4c
Elevation Inches	0.43	0.40	0.38	0.25	0.30	0.40

Based on these data, it is recommended that all drinking fountain bubblers which may at times extend upward through a water surface and with orifice not greater than 0.440 in. in diameter or 0.150 sq. in. of area shall be assembled at an elevation of 0.75 in., *i.e.*, the lower edge of the bubbler orifice shall be 0.75 in. above the flood level of the receptor. When a bubbler has more than one orifice, the sum of the areas of all orifices shall not exceed the area of a 0.440-in. diameter circle.

Since the shape and position of bubbler shields or guards has an influence on the elevation required, the safe elevation for a bubbler is not determined exclusively by the size of effective opening as is the case with ordinary spouts. However, the types tested included different

kinds of shields and guards. Furthermore a very liberal factor of safety was used as a basis for the recommended elevation, thereby allowing for variations and other extreme conditions, such as: variation in the condition of the metal surface over which the water is drawn during backflow; disturbed water surface; possible water meniscus above rim; and effect of a vertical side wall extending above flood level point. During these tests a side wall never was closer to the bubbler orifice than approximately 3 in.

Additional important points of interest are being included due to their close relation to this whole subject.

Types of Backsiphonage Preventers: Backflow preventers can be made: (1) with moving parts; and (2) without moving parts. The "moving parts" types have met with more approval from those who have made a study of the subject than the types without moving parts. Some of the reasons for this choice follow:

The "moving parts" types, when of satisfactory construction, work on the normal range of pressures in water systems, *i.e.*, the same device will work on either high or low supply pressure. Furthermore, a variation of back pressure, such as is caused by different types of water closets or other fixtures, does not produce unsatisfactory action. These are two important features.

The "no moving parts" types, on the other hand, usually require a change in proportion or detail of construction of certain parts in order to adapt them to the pressure conditions under which they are to be used.

For example, a preventer made to work on 15-lb. per sq. in. supply pressure usually spits or leaks from the air vents at a pressure of 75 lb. per sq. in. Conversely, a preventer made to work at 75 lb. per sq. in. supply pressure usually restricts the flow of water to such an extent that it does not provide sufficient water for the fixture at a pressure of 15 lbs. per sq. in. Furthermore, the "no moving parts" types inject a large amount of air into the water. This movement of air through the vents causes considerable noise. The leakage of water or the noise due to air flow, or a combination of both, might be rated as an objectionable nuisance, with the result that someone who uses the fixture might close the air vent openings to stop leakage and noise, thereby destroying its protective value.

A vacuum of 15 in. of mercury is sufficient for all tests of air gaps or backsiphonage preventers. Data based on experimental tests have been published to substantiate this statement. However, apparently,

there are many who still do not realize this fact, as we see specifications requiring tests at a vacuum of 26 in. of mercury or greater. Such high vacuums are much more difficult and expensive to sustain during test, and are unnecessary.

Existing installations are as dangerous as new ones, so it is very important to correct those that are not safe. Most supply fixtures can be replaced easily, or special adaptors can be installed to eliminate backflow.

Skepticism. If anyone is the least bit skeptical about the importance of the subject of protecting pure water in pipe systems, I suggest that he read, "The Hazard of Faulty Plumbing," by Myron M. Stearns, in the June, 1939 issue of *Survey Graphic Magazine.* Mr. Stearns' article indicates that the general public or laymen not connected with manufacturing, installing or inspecting plumbing fixtures are beginning to show concern about back flow.

There are those who continue to argue against the seriousness of back flow hazards. They base their argument on the theory of the improbability of the simultaneous appearance of those factors necessary to produce backflow. The answer to such an argument is that millions of fixture installations and millions of people are exposed, so that even the smallest percentage of probability becomes a serious matter. The argument also has been met by showing, in laboratory assemblies using transparent pipe, how backflow occurs and how effective backsiphonage preventers obviate such backflow. It also has been shown, by attaching recording gauges of the combination pressure-vacuum type to the piping installation of several large buildings, that a vacuum does occur in the piping under normal operating conditions.

Industrial Plant Problems. Piping installations in industrial plants present a great problem, particularly where chemical solutions are transported and where water is supplied from more than one source. One interesting case, which was reported in a daily newspaper, involved a nursery and greenhouse establishment where a mixture of water and manure was piped to fertilize different sections. The pump used to circulate the solution built up a pressure greater than the water pressure in the water mains, and due to a very careless valve and piping hookup some of the manure was forced into the water mains. Several parties in other buildings using water from these water mains first noticed an objectionable taste, and later a brown color was detected. A complaint resulted in an investigation that showed that these parties actually had been using water such as they feared was the case.

Air Velocity Through Backsiphonage Preventer. In some cases—for example in water closets—danger may exist even if the conditions are such as not to allow backflow of water. This is true because air flowing at a velocity greater than that caused by a vacuum that will lift water 1 in. in tube with submerged end will carry bacteria back into the water supply. In other words, if a backsiphonage preventer allows a vacuum of more than 1 in. of water to occur in the pipe connected to its outlet end under any vacuum that may occur in the supply piping, it is still liable to suck in contaminated air which, in turn, would pollute the water. This is the reason for one of the limitations included in the proposed standard for testing. Furthermore, it is one of the serious problems confronting backsiphonage preventers that do not have moving parts.

Liability. A recent case in Ohio may serve as an example of the liability involved when serving, for drinking purposes, water that is contaminated and unfit for human consumption. It is Yochem *vs.* Gloria, Inc., 134 O. S. 427 in the Ohio State Supreme Court, decided November 30, 1938.

Briefly, Yochem, the plaintiff, claimed that he became ill from water served him in Gloria, Inc., restaurant. The jury in the Court of Common Pleas returned a verdict for the defendant. The State Supreme Court reversed the judgment, and the case was remanded to the Court of Common Pleas for retrial. The court stated: "It seems difficult to find a clearer case of statutory adulteration than under circumstances where the owner of a restaurant so handles sewage as to cause it to reach the source of the water supplied to customers for drinking purposes."

Conclusion. Summing up all phases of our problem, there is one major point that we should all remember, namely, "An approved means of preventing backflow should be provided at every discharge opening connected to water mains or water supply systems." In closing I desire to emphasize the need for coöperation by all organizations toward establishing and recognizing a "standard" for "preventive means" and then adoption of new codes or revision of present codes to make the use of such "standardized means to prevent backflow" mandatory.

OUTBREAKS OF WATER-BORNE DISEASES IN THE NEW ENGLAND STATES, 1920 TO 1936.*

BY ARTHUR E. GORMAN**

[*Read September 12, 1939.*]

Your program committee has invited me to present to this Association information pertaining to outbreaks of water-borne diseases in the New England states for the seventeen-year period running from 1920 to 1936. As a native of New England, I am happy to do this, as the showing reflects credit on the water-works and public-health officials of this region and because being here gives me an opportunity to renew acquaintances with many friends in these two professions. The statistics used in this contribution are based on data collected by Abel Wolman and myself and presented in a monograph† published earlier in this year.

Decline in Typhoid-fever Death-rate. Before considering the record of outbreaks of water-borne disease, let us first direct attention to a comparison, since the turn of this century, of the typhoid-fever death-rates in New England with those in the United States within the Registration Area of the Bureau of Census (see accompanying figure and Table 1). During the 38 years from 1900 to 1937 inclusive, the highest typhoid-fever death rate in any one of the New England states exceeded the average rate for the United States in four years: 1904, 1914, 1915, and 1920. During this period, the national rate declined from 35.8 to 2.1 deaths per 100,000 population. The New England rates ranged from a high of 35.0 for the state of Maine in 1904 to a low of 0.1 for Rhode Island in 1937. The typhoid-fever death-rate in the United States Registration Area did not drop below 10.0 per 100,000 population until 1919. In New England, the first states to achieve this distinction were Massachusetts and Rhode Island

*Since the preparation of this monograph, information has been received from Charles D. Howard, Director, Division of Chemistry and Sanitation, New Hampshire State Board of Health, concerning outbreaks of water-borne diseases in two communities of that state:

Keene, Population 12,600. In October 1923 there was an outbreak of gastro-enteritis in Keene which apparently was water-borne. It involved an unknown number of persons, estimated at from 500 to 1,000. While the exact cause of the infection was not determined, the outbreak occurred while rather extensive timber-cutting operations were underway on the watershed of the brook serving as the source of the Keene public water supply, which was not treated at the time.

The Weirs Summer Colony. Population 3,000± (summer). There were two outbreaks at this summer colony; one in July 1936 and the other in August 1937. In each instance about 200 persons were ill with gastro-enteritis. This summer colony is within the city limits of Laconia, but the water supply to the colony was not the public supply of that city. Water service to the homes was furnished by a private company from Lake Winnipesaukee, with chlorination the only treatment. Small brooks receiving pollution discharged into the lake about 200 ft. from the water intake. Apparently the amount of chlorine used for disinfection was inadequate. The outbreak followed periods of heavy rainfall on the watershed of these brooks.

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†Gorman, A. E. and Wolman, Abel "Water-borne Outbreaks in the United States and Canada and Their Significance"—Jour. A. W. W. A. 31:2:1193, Feb. 1939.

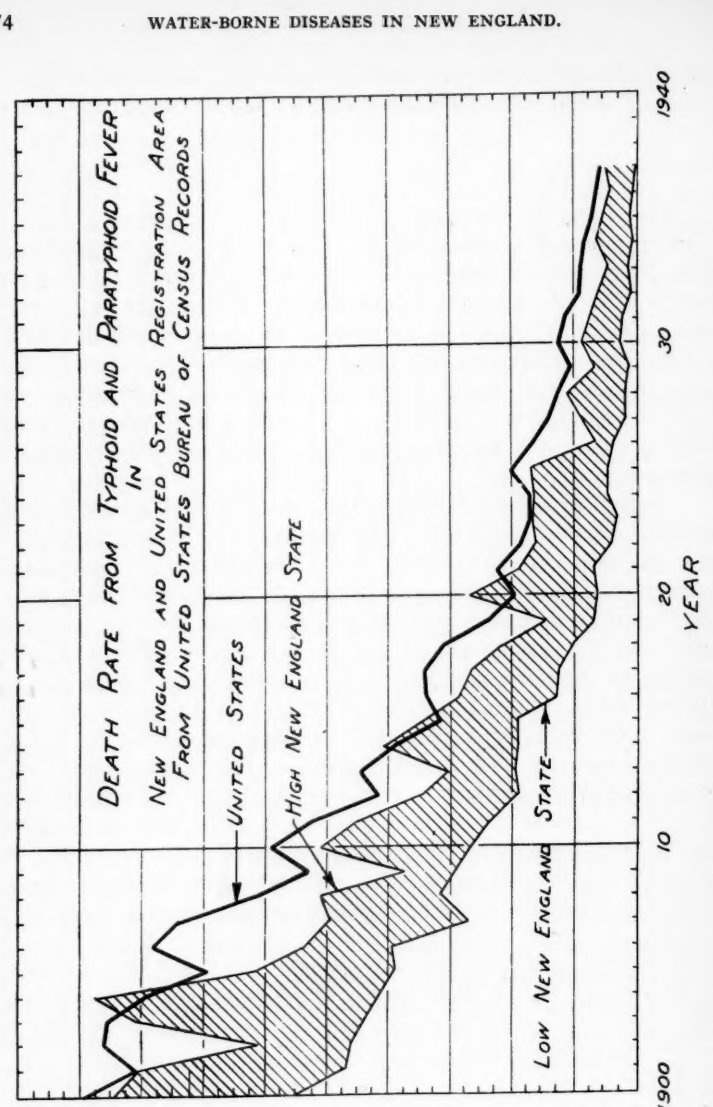
DEATH RATE FROM TYPHOID AND PARATYPHOID FEVER
IN
NEW ENGLAND AND UNITED STATES REGISTRATION AREA
FROM UNITED STATES BUREAU OF CENSUS RECORDS
UNITED STATES
HIGH NEW ENGLAND STATE
LOW NEW ENGLAND STATE
DEATHS PER 100,000 POPULATION
0
4
8
12
16
20
24
28
32
36
40
1900
10
20
30
1940
YEAR

TABLE 1—TYPHOID AND PARATYPHOID-FEVER DEATH-RATES PER 100,000 POPULATION IN THE NEW ENGLAND STATES, 1900 TO 1937.*

Death Rates per 100,000 Population.

Year	Maine	New Hampshire	Vermont	Massachusetts	Rhode Island	Connecticut	United States
1900	28.2	22.1	33.8	22.0	28.7	32.0	35.8
1	32.2	18.9	28.7	19.9	23.5	29.9	32.3
2	24.4	18.3	19.1	18.5	20.3	21.5	34.3
3	32.3	24.7	24.7	18.1	17.6	21.4	34.1
4	35.0	18.8	29.8	16.7	14.9	16.9	31.7
5	22.1	15.7	24.6	18.0	17.1	21.1	27.9
6	18.2	21.5	19.4	15.9	16.4	21.4	31.3
7	17.4	12.2	10.8	12.6	10.9	19.8	29.5
8	20.4	19.4	19.2	16.1	12.7	17.8	24.3
9	14.6	12.6	14.9	11.8	12.0	13.9	21.1
1910	20.3	10.7	14.0	12.5	13.6	14.7	23.5
11	18.1	14.6	12.4	9.1	9.6	13.4	21.0
12	13.8	8.8	11.3	7.7	7.9	10.7	16.5
13	12.1	12.0	7.9	7.9	8.5	11.1	17.9
14	16.2	8.7	11.9	7.7	8.6	9.0	15.5
15	13.6	7.8	13.3	6.8	10.6	12.1	12.8
16	11.3	5.0	6.5	4.7	7.2	7.2	13.3
17	10.8	6.1	7.1	4.9	5.8	9.0	13.5
18	7.7	4.5	8.5	4.1	5.7	5.4	12.6
19	5.7	3.4	3.1	2.7	3.3	4.0	9.2
1920	9.0	6.8	10.5	2.5	2.8	4.1	7.9
21	7.6	3.6	5.4	3.1	2.8	3.6	9.0
22	6.3	5.1	4.5	2.2	1.3	3.1	7.4
23	6.7	3.3	3.1	1.8	1.1	2.6	6.8
24	6.5	4.2	3.4	1.7	2.3	2.6	6.7
25	6.8	3.3	2.8	1.8	3.1	2.7	8.0
26	2.7	2.4	1.7	1.4	1.7	2.0	6.5
27	3.5	0.7	3.1	1.0	0.6	1.2	5.5
28	4.5	2.2	2.2	0.8	1.5	0.6	4.9
29	2.9	0.4	2.2	1.0	0.7	0.9	4.2
1930	3.6	1.9	0.8	0.9	1.6	1.0	4.8
31	3.1	2.1	1.6	0.7	1.0	1.2	4.5
32	2.4	1.7	0.5	0.6	0.3	0.6	3.7
33	1.8	0.8	0.8	0.6	0.4	0.5	3.6
34	2.4	1.6	2.1	0.3	0.7	0.4	3.3
35	2.0	1.2	1.1	0.3	0.3	0.8	2.8
36	0.8	1.0	1.6	0.2	0.4	0.5	2.5
37	1.9	1.0	0.8	0.4	0.1	0.3	2.1

*Statistics of the U. S. Bureau of Census Registration Area.

in 1911. The national rate dropped below 5.0 for the first time in 1928. The Massachusetts rate fell below 5.0 in 1916, and New Hampshire met this rate that same year.

For 30 of these 38 years, the typhoid-fever death-rate in the New England states was highest in Maine. Here the rate did not drop below 10.0 until 1918 nor below 5.0 until 1926. Vermont was high for 6 years and New Hampshire and Connecticut for one year each. Massachusetts had the lowest rate for 18 years, Rhode Island for 10, New Hampshire for 5, Vermont for 2, and Connecticut for 1 year. There were two ties, one between Massachusetts and Vermont in 1913 and the other between Massachusetts and Rhode Island in 1935. Altogether, the New England record of reduction in typhoid-fever death-rates is a distinguished one and reflects much credit on the public health and water works officials.

Outbreaks of Water-borne Diseases, 1920 to 1936 Inclusive. Having established this background of public-health achievement in the suppression of typhoid fever in general, we come to a review of the record of water-borne illnesses, in particular for the seventeen years 1920 to 1936 inclusive, both in the nation at large and in the New England states. Text books on public health ordinarily list as water-borne diseases: cholera, typhoid fever, bacillary dysentery and various gastro-intestinal disturbances of uncertain etiology commonly referred to as diarrhea or gastro-enteritis. During the last two decades epidemics of water-borne amebic dysentery, jaundice, and even brucelliasis have been added to this list. In addition, there have been, in recent years, a number of sharp outbreaks of diarrhea accompanied by vomiting where early circumstantial evidence suggested water as the probable source of infection, but where subsequent investigations could not prove or disprove this assumption; probably because the short duration of the illnesses made it impossible to conduct adequate epidemiological and laboratory studies. There appears to be a growing impression that these illnesses follow some unknown respiratory infection and that water may not be involved at all. Until much more dependable information is brought forward, however, it would seem prudent, at least for water-works and public-health officials, to proceed on the assumption that such outbreaks may have been water-borne and that all necessary precautions should accordingly be taken. I present this viewpoint not as an alarmist, but because experience in water-safety control-work convinces me that there are more potential hazards in the supplying of water to consumers than are generally realized and further because epidemics of the past have demonstrated

how terrible a toll a relaxation of our vigilance over water supplies, even for a short period of time, can exact. I know of no more fitting place than Montreal in which to mention the drastic penalties of a typhoid-fever epidemic in a modern community, for this city's record-breaking milk-borne epidemic of 1927 was responsible for over 5,000 cases and nearly 500 deaths.

In considering the outbreaks of water-borne diseases reported herein, I wish to make it clear that the outbreaks included were not limited to ones involving only municipal water-works systems. They include outbreaks in public and private supplies—either or both as the case may be—and may involve industrial plants, institutions, private homes, etc. In an Appendix to this report is given a summary of each of the outbreaks reported from the New England states. A comparison of the more important statistics is shown in Table 2.

TABLE 2—COMPARATIVE SUMMARY OF OUTBREAKS OF WATER-BORNE DISEASES IN THE UNITED STATES AND IN NEW ENGLAND, 1920 TO 1936.
Population in thousands

	United States	*New England*	
	Number	Number	Percent of U. S.
Population, 1930 Census	122,775	8,166	6.65
Water-borne Outbreaks Reported	399	23	5.7
Typhoid-Fever Cases Reported	12,585	222	1.8
Typhoid-Fever Deaths Reported	862	21	2.4
Diarrhea Cases Reported	103,032	3,778	3.7
Total Persons Affected	115,645	4,000	3.4

Comparatively, the showing of New England in number of outbreaks and number of cases of water-borne illnesses for this period was a good one. From a statistical standpoint, the number of outbreaks and cases in this region was too small to permit conclusions to be drawn with reference to water-supply practices, and none have been attempted. From experience covering more than two decades, the author is fully convinced that only a small percentage of water-borne illnesses is ever officially recorded and that the full facts relative to water-borne illnesses in any region or community will not be known until physicians and heads of institutions, and even families, are educated to report all gastro-intestinal disturbances coming to their attention.

New England has been most fortunate in its water-supply resources by having a relative abundance of lakes, ponds and available

streams draining sparsely settled watersheds. On the other hand, New England's public officials must be credited for the most part with foresight in protecting their water-supply resources from gross contamination, thus making it possible to use available sources without expensive treatment plants for clarification and purification. In this respect, this section has a distinct advantage over many other sections of the United States, and perhaps for this reason one should expect to find a lower index of water-borne illnesses. It must be recognized, however, that especially during the last decade, New England has experienced some very severe weather conditions which, but for alertness on the part of public-health and water-supply officials, might have seriously affected the safety of all types of water supplies.

Ownership of Water Systems. For the seventeen-year period 1920 to 1936 inclusive, there were reported by the engineering divisions of four of the New England states, 23 water-borne outbreaks with 222 cases of typhoid fever and 21 deaths and with 3,778 cases of diarrhea, a total of 4,000 persons affected (See Table 3). Two states, New Hampshire* and Connecticut, reported that no outbreaks of this character occurred during this period. Ten outbreaks appear to have been related to public water supplies, while in the remaining thirteen, private water systems were involved, as shown in Table 4.

This classification does not necessarily indicate that the public water supply involved was generally polluted and that infections were widely prevalent in the community. Outbreaks have been classed as involving public water supplies in those cases in which water used from the public water supply system became contaminated either in the distribution system or in the local system of a building or plant. The classification may be open to some criticism by those who feel that water works officials are not responsible for what happens to water on the consumer's premises. The author cannot agree with this position, as is discussed elsewhere in this article.

Eleven of New England's twenty-three outbreaks occurred in two individual years: six in 1934 and five in 1930. There were three each in 1932 and 1935, two in 1931, and only one in the years 1922, 1924, 1926 and 1927. No outbreaks were reported for the 8 years of 1920, 1921, 1923, 1925, 1928, 1929, 1933 and 1936.

Comparison with Other Regions. Compared with the other eight geographical groups of states in the nation, New England ranked third lowest in the number of outbreaks of water-borne diseases during the seventeen years from 1920 to 1936 (See Table 5). Her twenty-three

*See footnote at beginning of this paper.

TABLE 3—OUTBREAKS OF WATER-BORNE DISEASES IN THE NEW ENGLAND STATES, 1920 TO 1936 INCLUSIVE, CLASSIFIED BY YEARS.

State	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	Total
								Number of Outbreaks										
Maine	—	—	1	—	—	—	—	1	—	—	3	1	—	—	—	—	—	6
Vermont	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2	—	—	3
Massachusetts	—	—	—	—	—	—	—	—	—	—	2	1	3	—	4	3	—	13
Rhode Island	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
Total	—	—	1	—	1	—	1	1	—	—	5	2	3	—	6	3	—	23
								Cases of Typhoid Fever										
Maine	—	—	51	—	—	—	—	11	—	—	22	6	—	—	—	—	—	90
Vermont	—	—	—	—	17	—	—	—	—	—	—	—	—	—	73	—	—	90
Massachusetts	—	—	—	—	—	—	—	—	—	—	17	—	—	—	—	10	—	27
Rhode Island	—	—	—	—	—	—	15	—	—	—	—	—	—	—	—	—	—	15
Total	—	—	51	—	17	—	15	11	—	—	39	6	—	—	73	10	—	222
								Cases of Diarrhea										
Maine	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vermont	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Massachusetts	—	—	—	—	—	—	—	—	—	—	—	500	340	—	2763	175	—	3778
Rhode Island	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	—	—	—	—	500	340	—	2763	175	—	3778
								Total Persons Affected										
Maine	—	—	51	—	—	—	—	11	—	—	22	6	—	—	—	—	—	90
Vermont	—	—	—	—	17	—	—	—	—	—	—	—	—	—	73	—	—	90
Massachusetts	—	—	—	—	—	—	—	—	—	—	17	500	340	—	2763	185	—	3805
Rhode Island	—	—	—	—	—	—	15	—	—	—	—	—	—	—	—	—	—	15
Total	—	—	51	—	17	—	15	11	—	—	39	506	340	—	2836	185	—	4000

No outbreaks of water-borne diseases were reported for New Hampshire and Connecticut, but see footnote at beginning of this paper.

TABLE 4—OUTBREAKS OF WATER-BORNE DISEASES IN THE NEW ENGLAND STATES, 1920 TO 1936, CLASSIFIED AS TO OWNERSHIP OF SUPPLY.

Reported	Maine	Massa-chusetts	Rhode Island	Vermont	Total
		Public Water Supplies			
Number of Outbreaks	1	6*	1	2	10
Cases Typhoid Fever	11	10	15	30	66
Deaths Typhoid Fever	—	—	1	1	2
Cases Diarrhea	—	3433*	—	—	3433
Total Persons Affected	11	3443*	15	30	3499
		Private Water Supplies			
Number of Outbreaks	5	7	—	1	13
Cases Typhoid Fever	79	17	—	60	156
Deaths Typhoid Fever	12	2	—	5	19
Cases Diarrhea	—	345	—	—	345
Total Persons Affected	79	362	—	60	501

*Includes two outbreaks at Cohasset where according to recent information from the Massachusetts Department of Health, "the only evidence which points to the public water supply was the coincidence of the use of a group of tubular wells with the two outbreaks." "The possibility of these outbreaks having been due to respiratory origin has been given considerable credence by the members of the medical staff."

TABLE 5—REGIONAL DISTRIBUTION OF OUTBREAKS AND CASES OF WATER-BORNE DISEASES IN THE UNITED STATES, 1920 TO 1936.

Region	Population, 1930 U. S. Census	Out-breaks	Cases Typhoid	Cases Diarrhea	Total Persons Affected
New England	8,166,000	23	222	3,778	4,000
Middle Atlantic	26,261,000	98	2,697	3,136	5,833
East North Central	25,297,000	87	4,000	71,909	75,909
West North Central	13,297,000	53	1,388	3,510	4,926*
South Atlantic	15,794,000	58	1,268	7,277	8,545
East South Central	9,887,000	25	831	2,076	2,907
West South Central	12,177,000	13	199	560	759
Mountain	3,702,000	15	1,007	350	1,357
Pacific	8,194,000	27	973	10,436	11,409
Total	122,775,000	399	12,585	103,032	115,645*

*Includes 28 cases of jaundice reported from Kansas in 1935.

outbreaks represented 5.7% of the total of 399 for the United States. Only the so-called West South Central and Mountain regions, with 3.3 and 3.7% of the outbreaks respectively, were lower than the New England group. Using the ratios of the percentage of outbreaks and cases to the percentage distribution of population in the United States, a fairly accurate comparison can be made of the relative prevalence of water-borne diseases in the different parts of the country (See Table 6). On this basis, New England ranked third lowest—following the West

TABLE 6—REGIONAL RATIOS OF PERCENTAGE OF OUTBREAKS AND CASES TO PERCENTAGE OF POPULATION, FOR WATER-BORNE DISEASES IN THE UNITED STATES, 1920 TO 1936.

Region	Percent Population, 1930 Census	Outbreaks Ratio of Percent Outbreaks to Percent Population	Typhoid Fever Ratio of Percent Cases to Percent Population	Diarrhea Ratio of Percent Cases to Percent Population	Persons Affected Ratio of Percent Persons to Percent Population
New England	6.65	0.86	0.27	0.56	0.51
Middle Atlantic	21.39	1.15	1.00	0.14	0.23
East North Central	20.61	1.06	1.54	3.39	3.18
West North Central	10.83	1.23	1.02	0.31	0.40
South Atlantic	12.86	1.13	0.79	0.55	0.58
East South Central	8.05	0.78	0.82	0.25	0.31
West South Central	9.92	0.33	0.16	0.05	0.07
Mountain	3.02	1.22	2.65	0.10	0.40
Pacific	6.67	1.00	1.15	1.51	1.48

South Central and East South Central states—in number of outbreaks and second lowest—following the West South Central states—in cases of typhoid fever reported. In reported cases of diarrhea and total persons affected, her showing as a region is not as good, her rating being seventh and sixth respectively. This is due principally to one outbreak of diarrhea in Fitchburg, Massachusetts in 1934.

All but six of the 48 states reported one or more outbreaks of water-borne diseases during the 17-year period from 1920 to 1936 (See Table 7). Two of these six were New England states: Connecticut and New Hampshire.† Massachusetts reported none for the first decade of this period. The rating of the four New England states was as follows:

State	No. of Outbreaks	Cases Typhoid	Cases Diarrhea	Total Persons Affected
Maine	21st*	27th*	none	31st*
Massachusetts	8th*	38th	7th	7th
Rhode Island	35th*	40th*	none	41st*
Vermont	28th*	27th*	none	31st*
Total States Reporting	42	41	24	42

†See footnote at beginning of this paper.

TABLE 7—DISTRIBUTION OF OUTBREAKS AND CASES OF WATER-BORNE DISEASES IN THE UNITED STATES, 1920 TO 1936, BY STATES.

Outbreaks		Typhoid Fever		Diarrhea		Total Persons Affected	
State	Cases	State	Cases	State	Cases	State	Cases
Pennsylvania	60	Indiana	1,478	Michigan	46,372	Michigan	46,719
New York	30	New York	1,316	California	10,377	California	11,164
Indiana	27	Ohio	1,230	Illinois	9,614	Ohio	10,603
Maryland	26	Pennsylvania	1,112	Ohio	9,373	Illinois	10,257
Illinois	22	California	787	West Virginia	6,711	Indiana	7,948
California	18	Illinois	643	Indiana	6,470	West Virginia	7,217
West Virginia	18	West Virginia	506	Massachusetts	3,778	Massachusetts	3,805
Massachusetts	13	Kentucky	503	Missouri	2,114	Pennsylvania	2,838
Ohio	13	Utah	403	New York	1,410	New York	2,726
Wisconsin	13	Maryland	359	Pennsylvania	1,726	Missouri	2,470
Michigan	12	Missouri	356	Tennessee	1,100	Tennessee	1,147
North Dakota	12	Michigan	347	Minnesota	706	Minnesota	986
Kentucky	11	South Dakota	342	North Dakota	650	Kentucky	979
Minnesota	11	Wisconsin	302	Maryland	516	Maryland	875
Texas	11	Minnesota	280	Arkansas	500	North Dakota	791
Iowa	10	New Jersey	269	Mississippi	500	Mississippi	597
New Jersey	8	New Mexico	220	Kentucky	476	Arkansas	500
Virginia	8	Virginia	213	Arizona	350	Arizona	430
Missouri	7	Montana	205	Wisconsin	80	Utah	403
South Dakota	7	Alabama	184	Texas	60	Wisconsin	382
Alabama	6	Texas	163	Oregon	59	South Dakota	342
Maine	6	Washington	161	Georgia	40	New Jersey	269
Washington	6	Iowa	157	Iowa	40	Texas	223
Kansas	5	North Dakota	141	Virginia	10	Virginia	223
Tennessee	5						

TABLE 7—DISTRIBUTION OF OUTBREAKS AND CASES OF WATER-BORNE DISEASES IN THE UNITED STATES, 1920 TO 1936, BY STATES (*continued*)

Outbreaks		Typhoid Fever		Diarrhea		Total Persons Affected	
State	Cases	State	Cases	State	Cases	State	Cases
Idaho	4	Kansas	97			New Mexico	220
Utah	4	Mississippi	97			Montana	205
Mississippi	3	Maine	90			Iowa	197
New Mexico	3	Vermont	90			Alabama	184
Oregon	3	Arizona	80			Washington	161
Vermont	3	North Carolina	77			Kansas	125*
Arizona	2	Idaho	71			Maine	90
North Carolina	2	Tennessee	47			Vermont	90
South Carolina	2	Delaware	46			Oregon	84
Arkansas	1	Oklahoma	36			North Carolina	77
Colorado	1	Georgia	35			Georgia	75
Delaware	1	South Carolina	32			Idaho	71
Georgia	1	Colorado	28			Delaware	46
Montana	1	Massachusetts	27			Oklahoma	36
Nebraska	1	Oregon	25			South Carolina	32
Oklahoma	1	Nebraska	15			Colorado	28
Rhode Island	1	Rhode Island	15			Nebraska	15
						Rhode Island	15
Total	399		12,585		103,032		115,645

*Includes 28 cases of jaundice.

TABLE 8—CAUSES OF OUTBREAKS OF WATER-BORNE DISEASES IN NEW ENGLAND, 1920 TO 1936.

	Classification	Number of Outbreaks	Cases of Typhoid Fever	Cases of Diarrhea	Total Persons Affected
A-1	Contamination of brook or stream by pollution on watershed	5	17	2,733	2,750
A-2	Use of polluted water from a river or irrigation ditch—untreated	1	9	—	9
A-4	Contamination of spring or infiltration gallery by pollution on watershed	1	—	40	40
B-1	Surface pollution of shallow wells	4	64	125	189
B-5	Underground pollution of well or spring in creviced limestone or fissured rock	1	60	—	60
D-1	Inadequate control of filtration and allied treatment	1	—	100	100
F-3	Cross-connection with polluted water supply	6	65	50	115
H-2	Use of polluted water not intended for drinking purposes	2	7	30	37
H-3	Cause of outbreak undetermined	2	—	700	700
	Total	23	222	3,778	4,000

Causes of Outbreaks. The outbreaks of water-borne diseases in New England fall into nine of the thirty-one classifications used in the Gorman-Wolman monograph previously referred to (See Tables 8 and 9). The largest number of outbreaks due to a single cause, namely cross-sections, was six. Of these, three occurred in Massachusetts, two in Vermont and one in Rhode Island. In comparison with the entire United States during the 17-year period, the percentage of outbreaks due to cross-connections in New England was more than 2.5 times that in the nation, and over twice that in Canada. In percentage of typhoid fever cases due to this cause, New England's percentage was more than 1.7 times that of the United States and 3.6 times that of Canada (See Table 10).

The second largest number of outbreaks was five—all in

TABLE 9—CAUSES OF OUTBREAKS OF WATER-BORNE DISEASES IN NEW ENGLAND, 1920 TO 1936, CLASSIFIED BY STATES.

	Classification									
		A			B		D	F	H	
	1	2	4	1	5	1	3	2	3	Total
				Outbreaks						
Maine	2	1	—	3	—	—	—	—	—	6
Massachusetts	3	—	1	1	—	1	3	2	2	13
Rhode Island	—	—	—	—	—	—	1	—	—	1
Vermont	—	—	—	—	1	—	2	—	—	3
Total	5	1	1	4	1	1	6	2	2	23
				Typhoid Fever						
Maine	17	9	—	64	—	—	—	—	—	90
Massachusetts	—	—	—	—	—	—	20	7	—	27
Rhode Island	—	—	—	—	—	—	15	—	—	15
Vermont	—	—	—	—	60	—	30	—	—	90
Total	17	9	—	64	60	—	65	7	—	222
				Diarrhea						
Maine	—	—	—	—	—	—	—	—	—	—
Massachusetts	2,733	—	40	125	—	100	50	30	700	3,778
Rhode Island	—	—	—	—	—	—	—	—	—	—
Vermont	—	—	—	—	—	—	—	—	—	—
Total	2,733	—	40	125	—	100	50	30	700	3,778
				Total Persons Affected						
Maine	17	9	—	64	—	—	—	—	—	90
Massachusetts	2,733	—	40	125	—	100	70	37	700	3,805
Rhode Island	—	—	—	—	—	—	15	—	—	15
Vermont	—	—	—	—	60	—	30	—	—	90
Total	2,750	9	40	189	60	100	115	37	700	4,000

classification A-1: contamination of a brook or stream by pollution on the watershed. This was the fourth ranking cause of water-borne outbreaks in the United States and the third in Canada. These five outbreaks accounted for 17 cases of typhoid fever and 2,733 cases of diarrhea. Three outbreaks occurred in Massachusetts; the other two were reported from Maine. One of the latter consisted of eleven cases of typhoid fever among citizens of Van Buren who had visited in St. Leonard, New Brunswick, during the period of a sharp epidemic of typhoid fever in that city caused by pollution of the public water supply. The three Massachusetts outbreaks due to this cause were all reported as possibly related to public water supplies and involved cases of diarrhea only and no typhoid fever.

TABLE 10—COMPARISON OF OUTBREAKS AND CASES OF WATER-BORNE DISEASES DUE TO CROSS-CONNECTIONS, 1920 TO 1936.

	United States		Canada		New England States	
	Number	%	Number	%	Number	%
Outbreaks, Total	399	—	71	—	23	—
Outbreaks, F-3	40	10.0	9	12.7	6	26.1
Cases of Typhoid, Total	12,585	—	3,437	—	222	—
Cases of Typhoid, F-3	2,122	16.9	278	8.1	65	29.3
Cases of Diarrhea, Total	103,032*	—	3,510**	—	3,778	—
Cases of Diarrhea, F-3	8,514	8.3	0	0	50	1.3
Total Persons Affected	115,645	—	6,947	—	4,000	—
Total Persons Affected, F-3	10,636	9.2	278	4.0	115	2.9

*Includes 1,429 cases of dysentery.
**Includes 2,000 cases of bacillary dysentery.

Four New England outbreaks were due to surface pollution of shallow wells, classification B-1. They caused 64 cases of typhoid fever with 12 deaths and 125 cases of diarrhea. This cause was responsible for the largest number of outbreaks in the United States for the seventeen years—totaling 52. Three were in Maine and one was in Massachusetts. None involved public water supplies.

Seasonal Distribution. Seasonally, the New England outbreaks were evenly divided between the spring and fall months with eight outbreaks in each season (See Table 11). The low season was summer

TABLE 11—SEASONAL DISTRIBUTION OF OUTBREAKS OF WATER-BORNE DISEASES IN NEW ENGLAND, 1920 TO 1936.
Number of Outbreaks in each month

Month	Maine	Massachusetts	Rhode Island	Vermont	Total
Jan.	1	0	0	1	2
Feb.	0	1	0	0	1
Mar.	0	4	0	0	4
Apr.	1	0	0	1	2
May	0	1	1	0	2
June	0	1	0	0	1
July	1	0	0	0	1
Aug.	0	0	0	0	0
Sept.	2	1	0	1	4
Oct.	0	3	0	0	3
Nov.	1	0	0	0	1
Dec.	0	2	0	0	2
Total	6	13	1	3	23

with two outbreaks, while winter ranked third with five. The months of March and September each marked the beginning of four out-

TABLE 12—OUTBREAKS OF WATER-BORNE DISEASES IN NEW ENGLAND, 1920 TO 1936, CLASSIFIED BY SIZE OF COMMUNITY.

Population	Maine	Massachusetts	Rhode Island	Vermont	Total
		Outbreaks			
1,000 and Under	—	2	—	1	3
1,001 - 5,000	6	5	1	1	13
5,001 - 10,000	—	—	—	1	1
10,001 - 25,000	—	1	—	—	1
25,001 - 50,000	—	2	—	—	2
50,001 - 100,000	—	2	—	—	2
100,001 - 500,000	—	1	—	—	1
Total	6	13	1	3	23
		Cases of Typhoid Fever			
1,000 and Under	—	—	—	60	60
1,001 - 5,000	90	—	15	17	122
5,001 - 10,000	—	—	—	13	13
10,001 - 25,000	—	—	—	—	—
25,001 - 50,000	—	—	—	—	—
50,001 - 100,000	—	17	—	—	17
100,001 - 500,000	—	10	—	—	10
Total	90	27	15	90	222
		Cases of Diarrhea (All in Massachusetts)			
1,000 and Under	—	133	—	—	133
1,001 - 5,000	—	1,065	—	—	1,065
5,001 - 10,000	—	—	—	—	—
10,001 - 25,000	—	50	—	—	50
25,001 - 50,000	—	2,530	—	—	2,530
50,001 - 100,000	—	—	—	—	—
100,001 - 500,000	—	—	—	—	—
Total	—	3,778	—	—	3,778
		Total Persons Affected			
1,000 and Under	—	133	—	60	193
1,001 - 5,000	90	1,065	15	17	1,187
5,001 - 10,000	—	—	—	13	13
10,001 - 25,000	—	50	—	—	50
25,001 - 50,000	—	2,530	—	—	2,530
50,001 - 100,000	—	17	—	—	17
100,001 - 500,000	—	10	—	—	10
Total	90	3,805	15	90	4,000

breaks. August was the only month in which no outbreaks originated. Four of the Massachusetts outbreaks started in March and three in October.

Size of Community. The distribution of outbreaks by size of communities shows 13 or 56.5% in the population group from 1,000 to 5,000 (See Table 12). This is not quite twice the percentage rate for the United States, but agrees quite closely with the percentage of Canadian outbreaks. There were 122 cases of typhoid fever with 13 deaths in this group. The largest number of cases of diarrhea reported was in the population group from 25,000 to 50,000 and comprised 2,500 cases in the outbreak of March 1934 at Fitchburg, Mass.

The low percentage of outbreaks (13.0%) occurring in the communities with less than 1,000 population is striking in comparison with the experience for the nation (36.8%) and Canada (32.4%).

The percentage of typhoid fever cases confined to the group of cities in New England with 1,001 to 5,000 people was 54.9 or more than twice that for the United States as a whole (23.8%) but less than that for Canada (72.7%).

Largest Outbreaks. Table 13 summarizes the facts relating to six outbreaks of water-borne diarrhea in each of which 100 or more persons were made ill.

TABLE 13—LARGEST OUTBREAKS OF WATER-BORNE DISEASES IN NEW ENGLAND, *1920 TO 1936.*

City	State	Pop.	Year	Month	Cases of Diarrhea	Cases of Typhoid	Classification	Supply
Fitchburg	Mass.	40,700	1934	Mar.	2,500	0	A-1	Public
Cohasset	Mass.	3,080	1931	Mar.	500	0	H-3	Public*
Williamsburg	Mass.	1,990	1932	Oct.	200	0	A-1	Public
Cohasset	Mass.	3,080	1934	Mar.	200	0	H-3	Public*
Northfield	Mass.	1,820	1935	Feb.	125	0	B-1	Private
Fiskdale	Mass.	300	1932	Oct.	100	0	D-1	Private

*See footnote to Table 4.

It will be noted that all of these outbreaks happened in Massachusetts. In the largest outbreak, involving 2,500 cases at Fitchburg in March 1934, it was reported that these illnesses, mostly among consumers in the high-pressure system, were due to possible pollution on the watershed of the public supply on which a large number of men had previously been employed.

The largest typhoid-fever outbreak occurred in April and May 1934 at Websterville, Vermont; 60 cases and 5 deaths were reported.

The probable cause was held to be the pollution of a privately-owned water supply by seepage from a broken sewer which passed through slate formation overlying granite. The second largest typhoid outbreak was at Woodland (Baileyville P. O.), Maine in the summer of 1922. There were reported 51 cases of typhoid fever and 10 deaths—an unusually high fatality. Polluted wells that had been ordered closed on account of typhoid fever two or three years previous to this outbreak were opened by unauthorized parties, and the water was used by the residents in the vicinity.

Multiple outbreaks were reported for three cities during the seventeen year period: Bucksport, Maine, in 1930 and 1931; Cohasset, Mass., in 1931 and 1934; and Lawrence, Mass., twice in 1930. This does not necessarily mean that the outbreaks were due to the same cause, although this was probably true of the two Cohasset outbreaks, if definitely water-borne.

There were at least five outbreaks among employes at industrial plants. Four were due to cross-connections: Lawrence, Worcester, and North Adams, Massachusetts; and Winooski, Vermont. The fifth occurred at Fiskdale, Mass., and was due to the use of water from a polluted source after improper filtration in a private system at a mill.

No outbreaks in institutions, schools, summer camps or hotels were reported from New England. This is in striking contrast to the record for both the United States and Canada. In view of the popularity of New England as a resort and vacationing region, one might expect some outbreaks of water-borne diseases during the summer season. In New York State, during the last few years, special investigations of the sanitation of summer resorts have uncovered many outbreaks of water-borne diseases that might otherwise have never been officially disclosed. This experience makes one wonder whether or not a similar situation might be found to exist in New England.

Legal Responsibility. In the Winooski, Vermont, outbreak of typhoid fever in January 1934—caused by polluted water entering the city's water system through a cross-connection installed for emergency fire-service—the action of a jury in awarding damages to the plaintiffs —the heirs of a man who died of typhoid fever alleged to have been contracted by drinking polluted water from the city's system—was sustained by the State Supreme Court in November 1936.

The recent attitude of the courts toward responsibility for water-borne illness is most interesting. In Ohio since 1921 and in Michigan since 1923, the courts have held that typhoid fever contracted by an employe as a result of drinking impure water supplied by his employer

is a compensatable accident, within the meaning of the Workmen's Compensation Act.

The financial plight of the Chicago hotel in which the famous epidemic of amebic dysentery of 1933 originated is well known. The high cost of damages resulting from the two Fort Wayne, Indiana, outbreaks of 1923 and 1929 caused by cross-connections and from the Olean, N. Y., epidemic of 1928 furnishes only partial evidence of the economic penalties that are incurred when public water systems are permitted to become polluted. The recent decision of the Massachusetts Supreme Court in finding the town of North Attleborough responsible for the illness of a consumer by supplying lead-bearing water to his premises,—although the lead was dissolved apparently by the active water in passing through an unusually long service pipe,—bears tidings of a new legal viewpoint on the responsibility of water companies in serving the public.

Safeguarding Water Supplies to Consumers. There is a growing opinion that water-works operators—public or private—should be responsible up to the consumer's tap for the quality of the product they sell, and there is much merit in this viewpoint. Too many water-works and, I fear, even public-health officials concentrate on delivering a safe water to storage reservoirs and neglect the potential pollutional hazards in the distribution system. Others take the position that a safe supply delivered to the consumer's premises is the extent of their responsibility. This I believe is not a sound stand in the interests of the public. Such a policy may have been an underlying factor in many outbreaks due to cross-connections and may result in future epidemics. Many water-works officials assume that water flows always in one direction: from the public supply to the consumer. But this is not necessarily so, and in nearly every water works,—unless proper supervision is exercised over water systems on consumer's premises, and unless adequate pressures are maintained in the public system,—there may be periods when backflow of water from the consumer's system will occur. Elevated storage in high buildings, or high pressure in a secondary water-system on a consumer's premises, may result in backflow into the public distribution system. This may or may not be dangerous depending on the character of water used in the consumer's private system or the use he makes of water from the city's system and the type of plumbing fixtures supplied with water from the public system.

Repumping of water on private premises, through a direct suction-connection to the public system may, at times of low pressure or interruption of service due to closure of a valve, create a negative head in

the water pipes. Under such conditions, serious pollution of the public distribution system could occur if underground leaks exist near sewers or house drains or if the negative head causes back-siphonage of plumbing fixtures. One of the most common causes of localized contamination of water in large buildings is the occurrence of a negative head in water pipes on the suction side of house pumps.

Everything possible should be done to maintain adequate pressures in public water-distribution systems, and if shut-downs must be made or if shut-downs do occur due to accidents, proper precautionary measures should be taken. Responsibility for closing valves in water-distribution systems should definitely be assigned only to employes who understand the system and the full hydraulic effect of the closure. In hilly communities, a sudden draw-down of water due to a break in a main or the closing of a valve in a lower section of the system may cause considerable negative head in the mains at the crest of the system and create serious pollutional hazards.

The writer is of the opinion that a water utility has a definite responsibility for knowing what pollutional hazards exist on a consumer's premises and should not supply water service to hazardous premises unless proper precautionary measures are taken to protect the public supply. Other public utilities are most exacting in determining the use made by consumers of their service. They regulate unusual demands and pollutional hazards involving their service and equipment. Why should not water works officials take a similar stand, especially in the interest of public health?

However, it was not the purpose of this paper to treat the subject of safeguarding public water supplies from the source to the consumer, and time does not permit doing so. I do not wish, however, to conclude this paper on outbreaks of water-borne disease in New England with only praise for the fine record of the last two decades when a short sermon might not be untimely, for I am aware of the fact that in this region,—where industrial water supplies are numerous, where meteorological extremes may be expected periodically and where conditions favoring negative head in water systems are favorable due to the hilly nature of the topography,—distribution-system protection by maintaining residual chlorine in the water supply through to the consumer is not generally practised.

APPENDIX

CHRONOLOGICAL RECORD OF OUTBREAKS OF WATER-BORNE DISEASES IN NEW ENGLAND, 1920 TO 1936.

SYMBOLS

Sources of Water Supply

W	=	well, type not specified
L	=	lake
R	=	river
Br	=	brook
Sp	=	spring
SW	=	shallow well
TW	=	tubular well
DgW	=	dug well
S/res	=	shallow reservoir

Water Treatment

?	=	treatment unknown
N	=	no treatment
C	=	chlorination
F	=	filtration, type not specified
SF	=	slow sand filtration
RF	=	rapid sand filtration

Ownership of Supply

Pub	=	public
Pv	=	private
S Pub	=	semi-public
S Pv	=	semi-private

N.B. For definition of the nine symbols used under the heading "Classification," see Table 8.

TABLE 14—CHRONOLOGICAL RECORD OF WATER-BORNE OUTBREAKS IN NEW ENGLAND, 1920 TO 1936

City, Town or Institution	Population	Year	Month	Typhoid Fever Cases	Typhoid Fever Deaths	Diarrhea & Dysentery Cases	Water Supply Source	Water Supply Treatment	Classification	Cause of Outbreak and General Remarks
CONNECTICUT										
No water-borne outbreaks reported.										
MAINE										
Baileyville P.O. Woodland	2,240	1922	Jul. Sept.	51	10	—	SW	N	B-1	Polluted wells, ordered closed on account of cases of typhoid two or three years previous, were opened by unauthorized parties and used by houses in the vicinity.
Van Buren	4,594	1927	Nov. Dec.	11	—	—	Br	N	A-1	In town of St. Leonard, N. B., across St. John River from Van Buren a typhoid epidemic of severe proportions broke out apparently caused by public water system. Persons affected visited across river.
Madawaska	3,500	1930	Apr.-May	9	—	—	R	N	A-2	Three of 9 cases lived in Canada. Drank river water.
Belfast	4,990	1930	Sept.	6	—	—	W	N	B-1	Probably surface pollution of neighborhood well. Carrier not found.

TABLE 14—CHRONOLOGICAL RECORD OF WATER-BORNE OUTBREAKS IN NEW ENGLAND, 1920 TO 1936 (*continued*)

City, Town, or Institution	Population	Year	Month	Typhoid Fever Cases	Typhoid Fever Deaths	Diarrhea & Dysentery Cases	Water Supply Source	Water Supply Treatment	Classification	Cause of Outbreak and General Remarks
Bucksport	2,100	1930	Sept. Oct.	7	2	—	Dg W	N	B-1	Probable surface pollution of well used by restaurant. Carrier not found. Used also by neighbors.
Bucksport	2,100	1931	Jan.	6	—	—	Br	N	A-1	Water used from brook polluted upstream. Private source.
MASSACHUSETTS										
No water-borne outbreaks during 1920-1929.										
Lawrence	85,000	1930	Sept. Oct.	7	—	—	R,W,Sp	N	H-2	At picnic, water meant for washing only, faucet connected to polluted river-supply.
Lawrence	85,000	1930	Dec.	10	—	—	R	SFC	F-3	Private supply for fire protection and processes water obtained from polluted river cross-connected with public water system.
Cohasset	3,080	1931	Mar.	—	—	500	TW	N	H-3	Cause not definitely determined; evidence points to use of well water not chlorinated. The possibility of this outbreak having been due to respiratory origin has been given credence by members of medical staff.

TABLE 14—CHRONOLOGICAL RECORD OF WATER-BORNE OUTBREAKS IN NEW ENGLAND, 1920 TO 1936 (*continued*)

City, Town, or Institution	Population	Year	Month	Typhoid Fever Cases	Typhoid Fever Deaths	Diarrhea & Dysentery Cases	Water Supply Source	Water Supply Treatment	Water Supply Classification	Cause of Outbreak and General Remarks
Deerfield	2,880	1932	Mar.	—	—	40	Sp	N	A-4	Unsafe private water supply from spring.
Williamsburg	1,990	1932	Oct.	—	—	200	S/res.	N	A-1	Possible watershed pollution.
Fiskdale	300	1932	Oct.	—	—	100	R	F	D-1	Polluted private water supply at mill improperly filtered.
Cohasset	3,080	1934	Mar.	—	—	200	TW	N	H-3	Cause not definitely determined. Evidence points to use of well water unchlorinated. Possibly outbreak was of respiratory origin.
Fitchburg	40,700	1934	Mar.	—	—	2,500	S/res.	N	A-1	Possible watershed pollution. Large number of men employed on water shed. Outbreak mostly in high pressure system.
Pittsfield	49,680	1934	Oct.	—	—	30	Br.	C	H-2	Possible pollution of brook of private camp supply.
Monroe	Under 1,000	1934	Dec.	—	—	33	S/res.	N	A-1	Possible pollution on watershed of semi-public supply.

TABLE 14—CHRONOLOGICAL RECORD OF WATER-BORNE OUTBREAKS IN NEW ENGLAND, 1920 TO 1936 (*continued*)

City, Town, or Institution	Population	Year	Month	Typhoid Fever Cases	Typhoid Fever Deaths	Diarrhea & Dysentery Cases	Water Supply Source	Water Supply Treatment	Classification	Cause of Outbreak and General Remarks
Northfield	1,820	1935	Feb.	—	—	125	TW	N	B-1	Possible pollution of ground in vicinity of wells. Outbreak may have been associated with some food served.
Worcester	195,330	1935	May	10	2	—	S/res.	N	F-3	Outbreak possibly due to cross connection. Secondary supply chlorinated. Possible interruption of chlorination.
North Adams	21,620	1935	June	—	—	50	S/res.	N	F-3	Possible cross connection with grossly polluted private supply.
NEW HAMPSHIRE										
No outbreaks reported during 1920 to 1929, but see footnote at beginning of this paper.										
RHODE ISLAND										
Tiverton	4,300	1926	May-Jan.	15	1	—	—	—	F-3	Cross connection.
VERMONT										
Newport	4,980	1924	Sept.	17	—	—	L	N	F-3	Cross connections.
Winooski	5,300	1934	Jan.	13	1	—	Sp	N	F-3	Polluted Winooski river water entered city system through an 8-inch cross-connection at Woolen Mill.
Websterville	450	1934	Apr.-May	60	5	—	Sp	N	B-5	Probably broken sewer with seepage through broken slate formation overlying granite. Privately-owned water system.

Privately-owned water system.

DISCUSSION

BY FRANCIS H. KINGSBURY*

Mr. Gorman's paper calls for comment to make clear a difference in point of view held by Massachusetts under the existing conditions as to the classification of outbreaks of water-borne diseases.

At the beginning of this discussion, however, I wish to compliment Mr. Gorman on the thoroughness with which he has pursued his subject. The diagram showing the decrease in death rates from typhoid fever and paratyphoid fever in New England and in the United States Registration Area is particularly interesting. Consideration of this diagram and the data supporting it affords sanitary engineers in New England a considerable degree of satisfaction. But at the same time it causes them to realize their responsibility for maintaining the present favorable record and the necessity of accomplishing the same degree of relative freedom from other diseases that under certain conditions may be water-borne.

In Massachusetts, the Department of Public Health is charged by law with the care of inland waters. Under Section 17 of Chapter 111 of the General Laws its powers and duties with regard to water supply are set forth as follows:

"SECTION 17: The department shall consult with and advise the officers of towns and persons having or about to have systems of water supply, drainage or sewerage as to the most appropriate source of water supply and the best method of assuring its purity. . . . No person shall be required to bear the expense of such consultation, advice or experiments. Towns and persons shall submit to said department for its advice and approval their proposed system of water supply or of the disposal of drainage or sewage, and no such system shall be established without such approval. All petitions to the general court for authority to introduce a system of water supply, drainage or sewerage shall be accompanied by a copy of the recommendation, advice and approval of said department thereon. The department may after a public hearing require a city or town or water company to make such improvements relative to any existing treatment works as in its judgment may be necessary for the protection of the public health. . . ."

In addition, special legislative acts providing for the establishment of public water supplies in municipalities or districts have carried for a number of years the provision that all sources of water supply and means of treatment shall meet with the approval of the Department.

Section 159 of Chapter 111 of the General Laws provides for the general oversight and care of all inland waters as follows:

"SECTION 159: The department shall have the general oversight and care of

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all inland waters and of all streams and ponds used by any city, town, water supply or fire district or public institution or by any water or ice company in the commonwealth as sources of ice or water supply and of all springs, streams and water courses tributary thereto. It shall be provided with maps, plans and documents suitable for such purposes, and shall keep records of all its transactions relative thereto. It shall give notice to the attorney general of any violation of law relative to the pollution of water supplies and inland waters."

Section 160 of Chapter 111 of the General Laws permits the Department to make rules and regulations for preventing the pollution and securing the sanitary protection of public water supplies as follows:

"SECTION 160: The department may cause examinations of such waters to be made to ascertain their purity and fitness for domestic use, or the possibility of their impairing the interests of the public or of persons lawfully using them or of imperilling the public health. It may make rules and regulations to prevent the pollution and to secure the sanitary protection of all such waters used as sources of water supply. It may delegate the granting and withholding of any permit required by such rules or regulations to state departments, boards and commissions and to selectmen in towns, and to boards of health, water boards and water commissioners in cities and towns, to be exercised by such selectmen, departments, boards and commissions subject to such recommendation and direction as shall be given from time to time by the department; and upon complaint of any person interested, the department shall investigate the granting or withholding of any such permit, and make such orders relative thereto as it may deem necessary for the protection of the public health. Whoever violates any such orders, rules or regulations shall be punished by a fine of not more than five hundred dollars, to the use of the commonwealth, or by imprisonment for not more than one year, or both."

From time to time the Department has made rules and regulations for the protection of the sources of public surface-water supplies, an outline of which is shown in a paper by the writer published on page 90 of the March JOURNAL of this Association for the year 1939. On page 95 of that paper there is shown a list of the municipalities that have requested such rules and regulations.

In its investigations of cross-connections between public water supplies and private fire and industrial water supplies, the Department realized the necessity of greater control, and after consulting the Attorney General, the Department, acting under Section 160 of Chapter 111 of the General Laws, on February 9, 1937, adopted rules and regulations for the prevention of cross-connections as follows:

COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC HEALTH

Rules and Regulations Relative to Cross Connections Between Public Water Supplies and Fire and Industrial Water Supplies Adopted on February 9, 1937, by the Department of Public Health.

Rule 1. After December 31, 1937, no physical connection between the distribution system of a public water supply, the water of which is used for drinking and/or domestic and/or culinary purposes, and that of any other water supply shall be permitted, unless such other water supply is approved by the Department of Public Health as being of safe sanitary quality and the connection of both supplies is approved by the Department of Public Health.

No Officer, board, corporation or other person or group of persons, owning or having the management or control of any water supply, the water of which is furnished to any municipality or district for drinking and/or domestic and/or culinary purposes, shall supply water to any person, firm or corporation maintaining such a connection.

Provided: Where such physical connection exists on December 1, 1937, the date of discontinuance may be temporarily extended with the permission of the Department of Public Health provided it includes two gate valves with suitable indicators and two check valves with drip cocks, gauges for testing, all located in a pit or room having facilities for draining and readily accessible for periodic inspection and overhauling of the equipment, the entire installation and design of which are approved by the Department of Public Health.

Rule 2. If a public water supply, the water of which is used for drinking and/or domestic and/or culinary purposes, is used as an auxiliary supply delivered to a tank also supplied with water from a source with which cross connections are not permitted by Rule 1, such tank shall be subject to the approval of the Department of Public Health and shall be open to atmospheric pressure and the water shall be supplied to the tank above the maximum level of water in the tank. The tank overflow shall be of adequate size to fix definitely the maximum level.

If the water supply is stored in a tank supplied only from a water supply approved by the Department of Public Health for drinking and/or domestic and/or culinary purposes, is used as an auxiliary supply delivered to a tank also supplied with water from a source with which cross connections are not permitted by Rule 1, such tank shall be subject to the approval of the Department of Public Health and shall be open to atmospheric pressure and the water shall be supplied to the tank above the maximum level of water in the tank. The tank overflow shall be of adequate size to fix definitely the maximum level.

If the water supply is stored in a tank supplied only from a water supply approved by the Department of Public Health for drinking and/or domestic and/or culinary purposes and directly connected to a water supply, also approved by the said Department of Public Health, such tank shall be so constructed as to avoid any possible contamination of the water in the tank and shall be subject to the approval of the Department of Public Health.

By order of the Department of Public Health
Henry D. Chadwick, M.D.
Commissioner of Public Health.

The early investigations that initiated the establishment of the Massachusetts State Board of Health led to the general recommendation that such a board should be, for the most part, advisory. The General Court of Massachusetts has been conservative in holding to this point of view and has granted but few mandatory powers to the Department. The rules and regulations of the Department, however, may be enforced by the Supreme Judicial or Superior Court upon application of the Department or any party interested, as provided in Section 164 of Chapter 111 of the General Laws.

The Department has not the personnel nor the appropriation to undertake the constant detailed supervision necessary to prevent all violations of these regulations and must depend upon local authorities to a large extent.

The laws of Massachusetts give wide powers to local boards of health, and every municipality within the Commonwealth has such a board of health or health department. The powers and duties of local boards of health in Massachusetts are very extensive and may be interpreted as authorizing them to make rules and regulations with regard to public water supplies not inconsistent with those made by the Department of Public Health and boards of water commissioners.

In Massachusetts, water is supplied by three types of agencies. Charters are granted to municipalities to supply themselves with water, and similar charters are granted to legally defined districts within municipalities for supplying certain sections thereof with water; in addition, charters are granted to water companies for the distribution and sale of water.

There has been considerable discussion within this Association as to the advisability of extending the powers of the water departments to include supervision of all piping on private premises to the fixture from which the water is drawn. As a practical matter, most water departments and water companies at present consider their responsibility to terminate at the water meter where the service pipes enter private buildings, although the City of New Bedford has within a few years revised its ordinances to authorize and require the water department to be responsible for the protection of the water supplied all the way to the fixture.

In its investigations of cross-connections, the Massachusetts Department of Public Health has considered that its authority under the law extends only to such cross-connections as may be likely to affect the quality of the water in the public distribution system; and most water departments in Massachusetts, under existing laws and municipal

ordinances, consider that their authority is likewise limited under the present law. Whenever the Massachusetts Department of Public Health in its investigations discovers conditions within private property that might affect the quality of the water supplied on such premises for drinking or culinary purposes, it, as a matter of routine, notifies the local boards of health of such conditions and recommends that they be eliminated.

In Mr. Gorman's paper he refers to certain outbreaks of water-borne diseases as having been related to public water supplies and in his paper he states that "outbreaks have been classed as involving public water supplies in those cases in which water used from the public water supply system became contaminated either in the distribution system or in the local system of a building or plant." He anticipates that some criticism may be forthcoming from those who feel that water works officials are not responsible for what happens to water on a consumer's premises and he cannot agree with this point of view.

In these matters it must be recognized that the present legal set-up is of long standing and that the division of authority of the several local agencies is pretty much recognized in Massachusetts. Recent court decisions in Massachusetts, however, have adjudged water departments responsible for illness caused by the action of the water on lead pipes within the consumer's premises, indicating a responsibility of the water department for issuing warnings against the use of such pipes where water is corrosive or for correcting its corrosiveness before it is supplied. This decision was rendered in the North Attleborough case referred to in the author's paper. These and similar decisions of courts in other states may lead to changes in law that may place the responsibility on water departments to insure the safety of the public supply at the fixture; but until such changes in the law or in municipal ordinances are made, the water department should not be held responsible for defects or interior cross-connections on the private premises of the water consumer.

The author has mentioned a number of sharp outbreaks of diarrhea accompanied by vomiting, where circumstantial evidence suggested water as a probable cause, but which subsequent investigation could not prove or disprove to be water-borne because of the short duration of the illness. The Annual Report of the Commissioner of Public Health of Massachusetts for 1934 stated:

"... These were the type of cases that are frequently referred to as 'intestinal grippe.' Although there is no evidence that the etiologic agent is related to the organism that causes the usual type of grippe, there is increasing evidence that

there is some sort of gastro-enteritis that is spread through the respiratory tract. It is popular to attribute these incidents to a water supply as was done in three different communities, yet examination of the water showed no evidence of pollution and the distribution of the cases over a period of one to two months would definitely suggest some other mode of spread. . . . "

This same report referred to the extensive and explosive outbreak of gastro-enteritis in Fitchburg during that year. Subsequent to this report, similar occurrences have suggested that these conclusions may not have been sufficiently well founded. We must agree, however, with the author that until more dependable information is brought forward, it would seem prudent,—at least for water works and public health officials,—to proceed along the lines that such outbreaks may be water-borne and that all necessary precautions should be taken.

In his paper, the author makes reference to what he calls a striking contrast between the record for the New England States, as regards outbreaks at institutions, schools, summer camps and hotels, with a record for the United States as a whole and Canada, and he refers to special investigations of sanitation at summer resorts in New York that have uncovered many outbreaks of water-borne diseases that might otherwise never have been officially disclosed. He states that this experience makes one wonder whether a similar situation might be found in New England.

Many of the camps established by such organizations as the Girl Scouts and Boy Scouts and professionally-operated camps have attendant physicians who may be relied upon to report outbreaks of intestinal disease to the proper authorities, and the State District Health Officers in Massachusetts are closely in touch with their districts and may be expected to be familiar with such outbreaks. Accordingly, it is my belief that the favorable record for Massachusetts may stand as recorded.

As an additional safeguard to the public, Massachusetts has, during the current year, enacted legislation requiring the licensing of recreational camps, overnight camps or cabins and trailer camps, the issuance of licenses being contingent upon approval by the State Department of Public Health of the source of water supply and the works for the disposition of sewage. This law also provides for the adoption of rules and regulations by the local boards of health. The adoption and enforcement of this legislation will furnish the visitor to Massachusetts additional assurance of safety.

In conclusion, I must agree with the author that adequate supervision must be maintained of the public water supply until the water

is drawn by the consumer. There must be coördination of the work of the several public officials charged with this responsibility, though this work is divided at present.

BY WARREN J. SCOTT*

I feel that the waterworks profession and public health workers owe a debt of gratitude to Mr. Gorman and Mr. Wolman for their painstaking reports on the prevalence of outbreaks of water-borne diseases in this country for a number of years past. They bring a lesson and spell a warning for all of us.

While Connecticut had no record of water-borne diseases to report during the period between 1920 and 1936, we did have a small outbreak of minor intestinal upsets last year which we believe was due to a small factory-owned village water supply. The supply is a surface water from a watershed free of any permanent habitations. Chlorination was temporarily interrupted a short time prior to the outbreak. No definite source of pollution could be traced, but it seemed logical from the epidemiological evidence to conclude that chance pollution may have been responsible.

Mr. Gorman refers to our fortunate position in having available many relatively unpolluted water sources and compliments New Englanders on their foresight in protecting their water supplies against contamination. While much may be said for or against the economics of constructing long pipe lines to convey water to our cities and towns from clean watersheds as against using nearby polluted sources with extensive treatment, it is a fact that the use of relatively unpolluted sources, as in the Boston area, the Hartford area and many other localities, greatly lessens the opportunities for spread of water-borne infections. The best of treatment plants may fail, and the cost of these developments appears warranted from a public health standpoint. Another factor that undoubtedly enters into the picture is that, in connection with the development of these distant sources of water supply from somewhat limited watershed areas, it has been necessary to develop long storage to carry the supplies through drought periods. The history of eastern water supplies in the United States during periods when no treatment of the water has been provided, testifies to the effectiveness of storage in helping to make water supplies safe, even though this effectiveness may fail under conditions of heavy run-off and treatment of all surface water is unquestionably necessary.

*Director, Bureau of Sanitary Engineering, Connecticut State Department of Health.

In Connecticut only about 1% of the population supplied with water from public systems now receives untreated surface water, and this small percentage is diminishing. We do not, in many instances, have residual chlorine carried through to all taps as suggested by Mr. Gorman. I wonder how effective even this safeguard is against entrance of real slugs of pollution into distribution systems, especially bearing in mind the relatively small quantities of available disinfectant that can be carried in distribution systems and the somewhat slow disinfecting ability of chloramines. To safeguard against pollution peaks on unfiltered surface water supplies after heavy run-off, super-chlorination followed by de-chlorination may be the ultimate answer. In Connecticut, we are now making exhaustive bacteriological studies of three distribution systems over a period of a year, and these are being correlated by field surveys. We hope to obtain information of value.

Mr. Gorman rightly stresses the importance of safeguarding distribution systems against secondary contamination and the need for some agency, whether the water utility or the health department, to check up on pollution of water supplies in buildings. We have already instituted many surveys of cross-connections and water storage in Connecticut buildings by local health departments but appreciate that much remains to be done. Occasional check-ups are not enough. There should be continual surveys on all water supplies. The protection is well worth the expense.

PROCEEDINGS

Fifty-Eighth Annual Convention

Montreal, Canada

September 12 to 15, 1939.

The following is a synopsis of those parts of the proceedings of the Fifty-eighth Annual Convention that appear to be of value for the record.

The Fifty-eighth Annual Convention of the New England Water Works Association was held at the Windsor Hotel, Montreal, Canada, September 12 to 15, 1939.

Tuesday, September 12

Morning Session

The convention was called to order by President George A. Sampson.

The President announced the death of John William Kay, Superintendent of the Milford Water Company.

Secretary Gifford announced the election by the Executive Committee of the following:

Members: Harry E. Jordan, Secretary, American Water Works Association, Port Washington, N. Y.; Walter J. Shea, Engineer, Rhode Island Department of Health, Providence, R. I.; Clifford O. Duval, Water Commissioner, Bourne, Mass.; Leonard William Trager, Associated Sanitary Engineer, New Hampshire State Department of Health, Concord, N. H.; Frank Dingley Lord, Chemist with Goodall Worsted Co., Kennebunk, Me.; Theo. J. Lafreniere, Public Health Engineer, Ministry of Health, Montreal, P. Q.; Sydney C. Beane, Superintendent, Weymouth Water Works, Weymouth, Mass.; Samuel W. Bowers, Superintendent and Engineer, Southington Water Department, Southington, Conn.; Harold Wallace Baker, City Manager, Rochester, N. Y. (reinstatement).

Associates: Fred A. Houdlette and Son, Inc., Boston, Mass.; (reinstatement); Lead Industries Association, New York, N. Y.; Joseph Dixon Crucible Co., Jersey City, N. J. (reinstatement); Boston Edison Company, Boston, Mass.

Administrative Reports

The Annual Reports of the Secretary, Treasurer, Editor and Finance Committee were presented (see p. 521), accepted and ordered to be printed in the JOURNAL.

The Annual Report of the Legislative Committee was read by Arthur C. King, Chairman, accepted and ordered placed on file (see p. 531).

Closing of Polls and Appointment of Tellers

The President declared the polls closed and appointed Arthur C. King, George G. Bean, and William P. Melley as tellers to canvass the ballots.

Luncheon Session

The luncheon meeting was addressed by His Worship, Camillien Houde, Mayor of Montreal, who welcomed the Association to Montreal. His Worship was introduced by Charles J. Des Baillets, President of the Canadian Section of the American Water Works Association and Chief Engineer of the Montreal Water Board.

Award of the Dexter Brackett Memorial Medal

THEODORE REED KENDALL. The Committee on the Award of the Dexter Brackett Memorial Medal was composed of Horace J. Cook of Auburn, Me., Clarence M. Blair of New Haven, Conn., and myself. We wish that every member of this Association were a member of this committee, because every member would then read every paper carefully.

We approached our task humbly but not with too great awe, lest we follow what almost seemed to be the fashion, namely awarding the medal to the longest paper published. We did, however, agree immediately on the leading papers published in the JOURNAL of the Association last year and chose for the medal a paper that we felt was of genuine historical value, practical, useful, and had cost data and methods carefully delineated.

When the other two members of the Committee reported their choice to me, each of them specifically stated, "We wish to have you tell the Association that we believe the paper that we consider our second choice should have honorable mention." In following the instructions of my Committee, in which I most heartily concur, I want to tell you that the paper to which the Committee would award hon-

orable mention is that entitled "Economics of Water Purification," by E. Sherman Chase and Arthur L. Shaw.

The paper that received the Award of the Dexter Brackett Memorial Medal is that prepared by Roger W. Esty. It was not the longest paper, but he prepared it alone. He did not have a large organization behind him. He devoted his time and his energy and his care to the preparation of a paper that we consider most useful.

Mr. Esty has received many other honors from this Association. He has been a Director, a Vice-President and President of the Association. But that is not all. He does not consider that honors are first. He has been one of the hardest workers in the Association. The list of committees of which he has been chairman or a member runs on and on; I shall not list them. Many of you have served with him on these various committees and know what a hard worker he has been.

It gives me the greatest pleasure as Chairman of the Committee this year, to award the medal to a man whom we hold in high esteem and affection—Roger W. Esty. (Presenting medal to Mr. Esty.) (Applause.)

ROGER W. ESTY. It was indeed a real surprise when I received a letter from our President notifying me that I was to receive this medal. Little did I realize when I wrote the paper that it would ever be given such consideration. My only thought was to prepare the paper in order to give to members of this Association our experience on that particular job. I thought it was particularly interesting. We had unusual problems to meet. We are a little, small organization, and we went at the work ourselves, and we had, I feel, very good results.

I feel it an honor and a privilege to be a member of this Association. There is no other association that I know of that has the class and the caliber of men who make up this group. So, Mr. Chairman, it is with a great deal of pleasure and appreciation that I accept this Medal, and I don't know how I can express it any more than to say the simple words, I thank you. (Applause.)

Afternoon Session

A paper "Evolution in the Design of Concrete Pipe," was read by Charles J. Des Baillets, Chief Engineer, Montreal Water Board, Montreal, Que. E. J. Cleary, Linn H. Enslow, W. S. Lea, William W. Brush, Samuel M. Ellsworth, and F. F. Longley took part in the discussion.

A paper "Water Borne Outbreaks of Disease in New England," was read by Arthur E. Gorman, Engineer of Water Purification, Chicago, Ill. Francis H. Kingsbury, Warren J. Scott, E. Sherman Chase, Harry G. Hunter, Charles L. Pool, Paul F. Howard, Percy R. Sanders, Linn H. Enslow, and Gordon M. Fair participated in the discussion.

A paper "Standards of Water Quality," was read by Franklyn J. Lammers, International Filter Company, New York, N. Y.

A paper "Sodium Hexametaphosphate as an Aid in the Control of Corrosion," was read by Owen Rice, Research Engineer, Hall Laboratories, Pittsburgh, Pa. Henry T. Gidley, Gordon M. Fair, Sidney S. Anthony, F. J. Lammers, George F. Merrill, Linn H. Enslow, and Percy R. Sanders took part in the discussion.

Wednesday, September 13

Morning Session

President George A. Sampson in the chair.

Warren J. Scott presented the 1939 Report of the Committee on Research and Water Works Practice. This report was accepted and referred to the Executive Committee.

A paper "Conditions Covering the Installation of Lead Service Pipe," was read by Robert L. Ziegfeld, Lead Industries Association, New York, N. Y. Warren J. Scott, Robert Dick, Percy A. Shaw, Henry T. Gidley, Francis H. Kingsbury, E. Sherman Chase, Donald C. Calderwood, Linn H. Enslow, and Charles L. Pool took part in the discussion.

A paper "An Appraisal of PWA and WPA in New England," was read by William W. Brush, Editor, Water Works Engineering, New York, N. Y. Francis H. Kingsbury, Warren J. Scott, Theo. J. Lafreniere, Samuel M. Ellsworth, Harry E. Holmes, E. J. Cleary, and E. Sherman Chase took part in the discussion.

A paper "100 Years in the Water Works Field," was read by S. W. Kitson, Worthington Pump and Machinery Corporation, Harrison, N. J.

Thursday, September 14

Morning Session

President George A. Sampson in the chair.

A Progress Report of the Committee on Rainfall and Yield of Drainage Areas was read by Francis H. Kingsbury.

The PRESIDENT. A part of the program this morning is a paper upon "Waterworks Practice in England." It is a keen disappointment that the author of this paper, Mr. John Bowman, on account of the war in Europe, has found it impossible to be here today to present this paper in person. It is doubly so because Mr. Bowman is President of the Institution of Water Engineers in England, and the New England Water Works Association has recently concluded with the Institution of Water Engineers a reciprocal arrangement for the presentation of papers. I have asked Mr. E. Sherman Chase, who is Chairman of this Committee on Reciprocal Relations with the Institution of Water Engineers, to give you an outline of this interchange of papers, and then to read Mr. Bowman's paper.

E. SHERMAN CHASE. This matter of reciprocal relations with the Institution of Water Engineers may be divided into two parts. The first part is one of two or three years' standing. The exchange of papers between the two associations was first put into effect three years ago, when Mr. Gourley of the firm of Binnie, Deacon and Gourley of London, presented a paper. Last year Mr. Saville of Hartford presented a paper before the Institution of Water Engineers, and, incidentally, that paper received one of the awards of recognition by the Institution. This year Mr. Bowman is presenting a paper in absentia, although he had booked passage on a boat leaving Glasgow on the very day that Herr Hitler marched into Poland.

The second phase of reciprocal relations deals with mutual recommendation of outstanding papers published by the two societies, not necessarily recognition of the exchanged papers, although those exchanged papers might be among those considered for recognition. The scheme in brief is for each association to review at four-yearly intervals papers that it has published and to submit a list of perhaps four of these papers to the other society for a committee of that association to select the one most valuable to the association that it represents. In other words, every four years a committee from this Association would review the papers of the previous four years, select, say, four, and submit that list of papers to the committee of the Institution of Water Engineers, and that committee would select the one which it thought best for their purposes and issue a certificate of recognition, which would read in the case of the Institution something as follows: "The Institution of Water Engineers, London, England. This diploma for the year —— has been awarded by the Institution to Richard Roe of the New England Water Works Asso-

ciation, in the United States of America, in recognition of the merits of his paper on ————, which has been published in the Journal of the Association and reproduced in the Transactions of the Institution. This award is likewise a token of the high esteem of the Institution for the work of the Association in promoting the advancement of water engineering. The seal of the Institution is hereby affixed on this date, in such and such a year, in the presence of, and signed in the presence of the Secretary." A similar certificate or diploma, reading in a little different way, would be presented by this Association to some member of the Institution of Water Engineers.

The committee of this Association was appointed last November by your president and has presented the reports to the Executive Committee, been in correspondence with the Institution of Water Engineers, and both the Executive Committee of this Association and the Council of the Institution of Water Engineers have formally approved and ratified this exchange of mutual recognition. It will be arranged so that awards are alternated at two-yearly intervals.

This is the first public announcement of this arrangement, and in connection with this announcement, Mr. President, with your permission I wish to offer the following motion:

> That the New England Water Works Association, through its secretary, advise the Institution of Water Engineers of its gratification at this tangible expression of mutual respect and good will. (The motion was duly seconded and unanimously carried.)

A paper "Waterworks Practice in England," prepared by John Bowman, City Water Engineer, City Corporation, Edinburgh, Scotland, was read by E. Sherman Chase. Written discussions were submitted by Caleb M. Saville, Manager and Chief Engineer, Water Bureau, Metropolitan District Commission, Hartford, Connecticut; Robert Spurr Weston, Consulting Engineer, Boston; and Thomas H. Wiggin, Consulting Engineer, New York City. E. Sherman Chase, William W. Brush, E. J. Cleary, Karl R. Kennison, F. Y. Dorrance, and Francis H. Kingsbury took part in the discussion.

E. SHERMAN CHASE. May I add the following motion?

> That the incoming President of this Association be instructed to express to the Institution of Water Engineers and to Mr. Bowman our appreciation of his excellent paper, and our regret that the circumstances are such as to have prevented its presentation by Mr. Bowman in person. (The motion was duly seconded and unanimously carried.)

A Progress Report of the Committee on Meter Specifications was read by W. C. Hawley.

Afternoon Session

A paper "New Priming Systems for Use with Centrifugal Pumps," was read by Frank A. Broadhurst, Turbine Equipment Company, Boston, Mass. Warren J. Scott, Percy R. Sanders, and George F. Merrill took part in the discussion.

A paper "Significant Experiences in the Treatment of Water in New York State," was read by Charles R. Cox, Chief, Bureau of Water Supply, Division of Sanitation, State Department of Health, Albany, N. Y. Warren J. Scott, F. J. Lammers, Thomas H. Wiggin, Paul Hansen and Linn H. Enslow participated in the discussion.

A paper "Construction and Operation of Rapid Sand Filters at Lawrence, Mass.," prepared by Arthur L. Shaw and E. Sherman Chase, Consulting Engineers, Metcalf and Eddy, Boston, Mass., was read by Mr. Chase. Francis H. Kingsbury presented a written discussion.

A paper "Back Flow in Plumbing Systems," prepared by R. H. Zinkil, Consulting Engineer, Crane Company, Chicago, was read by W. A. Dallach of the Crane Company.

FRIDAY, SEPTEMBER 15

Morning Session

President George A. Sampson presiding.

REPORT OF TELLERS OF ELECTION

Number of Ballots cast	216
Number of Ballots counted	215
For President, Percy A. Shaw	215
For Vice-President, Francis H. Kingsbury	213
For Director, Karl R. Kennison	215
For Treasurer, Abel Reynolds	212
Blanks	1

(Signed) GEORGE G. BEAN
WILLIAM P. MELLEY
ARTHUR C. KING, *Chairman.*

The President then read his Presidential Address (see p. 515).
The President then introduced the President-Elect.

PERCY A. SHAW. I want to thank the membership for the honor conferred on me at this time. I realize the responsibility and

the difficulty of doing a good job in the one year allotted. I feel as if I should do all I can, because I doubt if anybody has obtained more benefit from the New England Water Works Association in the last five or six years than I have. When I went to Manchester I had not managed a water works previously. My work had been almost entirely engineering, and I had to learn fast. Thanks to the New England Water Works Association, I was able to learn apparently as rapidly as was necessary. So that I really feel quite a debt of gratitude to the New England Water Works Association, and shall do all I can in the coming year to keep it successful. I thank you. (Applause.)

Superintendents' Session

Sidney S. Anthony, Engineer and Superintendent of the Augusta Water District, Augusta, Me., presiding.

A paper "Protection of Standpipes," was read by H. G. Hunter, Assistant Engineer with W. S. Lea, Consulting Engineer, Montreal, Que. William W. Brush, W. C. Hawley, Walter B. Bushway, Marshall B. Palmer, Percy R. Sanders, Donald C. Calderwood, Harry E. Halpin, and Roger W. Esty took part in the discussion.

A paper "Some Problems of Winter Operation," was read by Allan K. Grimmer, Town Manager, Temiskaming, Que. Allen M. Symonds, Donald C. Calderwood, A. Dougrey, and Roger W. Esty took part in the discussion.

A paper "River Crossings," was read by Garden T. Heeney, Resident Engineer, Pumping and Filtration Plant, Ottawa, Ontario. Marshall B. Palmer, Thomas H. Wiggin, W. S. Lea, and Linn H. Enslow took part in the discussion.

A paper "Some Phases of Public Relations," was read by Harold L. Brigham, Superintendent, Water and Sewage Commission, Marlborough, Mass. Francis H. Kingsbury, Abel Reynolds, Leland G. Carleton, Donald C. Calderwood, W. C. Hawley, Percy R. Sanders, Linn H. Enslow, M. J. Rutledge, Percy A. Shaw, Arthur C. King, and George A. Reed took part in the discussion.

WILLIAM W. BRUSH offered the following resolution:

That a vote of thanks be extended to His Worship, Mayor Houde, the Montreal City Government, the Montreal Water Board, its Chief Engineer, Charles J. Des Baillets, Mr. J. H. Dougherty, Mrs. Dougherty, the Chairman, and the other ladies of the Reception Committee, the Water Works Manufacturers

Association, and all others who have so kindly and effectively cooperated in aiding in making the Fifty-eighth Annual Convention of the New England Water Works Association a success. (The motion was duly seconded and unanimously carried.)

The PRESIDENT. It is not the custom to include in such a resolution as this any member of the New England Water Works Association, but if it were, I am sure that Mr. W. S. Lea, for his work on the Program Committee, would be entitled to be included in this list.

The PRESIDENT. This concludes the Fifty-eighth Annual Convention of the New England Water Works Association.

(Adjourned)

NOVEMBER 1939 MEETING

HOTEL STATLER, BOSTON, MASS.

THURSDAY, NOVEMBER 16, 1939

President Percy A. Shaw in the chair.

Secretary Gifford announced the election to membership by the Executive Committee of the following:

Lazarus Rubin, Senior Chemist, Water and Sewerage Laboratories, Massachusetts Department of Public Health, 164 Frankin Street, Malden, Mass.; William Francis Herlihy, Water Commissioner of Haverhill, 30 Blossom Street, Haverhill, Mass.; Thomas Stimpson Laurence, Superintendent, Groton Water Works Company, Groton, Mass.; John Howland Robinson, Superintendent, Water and Sewer Department, Box 148, Concord, Mass.; Sidney Albert Thompson, Chief Engineer and Plant Superintendent, Citizens Water Company, 314 North Fourth Street, Burlington, Iowa.

Secretary Gifford presented the following resolution:

WHEREAS the October-November issue of the monthly publication of the Massachusetts State Planning Board entitled, "A Planning Forum" contains the following paragraph in an article entitled "Water Resources Problems of Worcester County":

> "The new Quabbin Reservoir and its immediate watershed probably represent the greatest opportunity for the development of inland water recreation in New England. Although it is difficult for us in New England, where water is so plentiful, to accept for supply purposes water that is anything short of virgin purity, this is really a narrow point of view and has resulted in greatly restricting our recreational opportunities through-

> out the Commonwealth by eliminating many lakes and ponds because of their use as water supply. From a strictly scientific point of view it is possible for considerable controlled recreation to take place on a lake or watershed without jeopardizing the quality of the water. This should be especially true in the case of the Quabbin Reservoir, not only because of its great size, but because of its distance from Boston, the ultimate place of water consumption, which would allow ample time for the natural purification of water as it passed through Wachusett and the detection of pollution if any still remained."

And, WHEREAS, appearing in an official publication of an agency of Government, it appears to reverse the long-established policy of sanitarians in New England for the protection of public water supplies. BE IT RESOLVED THEREFORE that the New England Water Works Association hereby places itself on record against the use of water supply ponds, lakes and reservoirs for recreational purposes and that a copy of this resolution be sent by the Secretary to the Massachusetts State Planning Board.

A paper "Real Estate Acquisitions for Metropolitan Boston's Water Supply in the Swift River and Ware River Watersheds," illustrated, was read by James A. Christenson, Civil Engineer, Metropolitan District Water Supply Commission, followed by discussion by the President.

A paper "The New Plumbing Testing Laboratory in the New Bedford Vocational School," illustrated, was read by Arthur V. Harrington, Assistant Engineer, Massachusetts Department of Public Health, and was discussed by the President and Stephen H. Taylor.

A paper "Brookline's Spheroidal Tank," illustrated, was read by Walter B. Bushway, Superintendent, Brookline Water Works, Brookline, Mass., and was discussed by the President and Charles L. Pool.

(Adjourned)

PRESIDENTIAL ADDRESS

THE STATUS OF THE NEW ENGLAND WATER WORKS ASSOCIATION

By GEORGE A. SAMPSON, Retiring President

Anyone who has read the presidential addresses to this Association for the past ten years, as I have recently done, will realize that little remains to be written. Not only has the history of the Association since its founding in 1882 been fully presented, but all phases of its activities have been thoroughly discussed.

It seems to be the well founded opinion that the usefulness of the Association is measured largely by the growth in membership, the value of the papers presented before the Association and later published in the JOURNAL, the attendance at the meetings, the work of the committees, its financial condition, and the benefits that are offered to the members.

It is the purpose of this address to give you the present status of the Association based on these standards. At the same time, the statistics herein compiled will be of value for future reference.

Membership. There is no doubt that a normal increase in membership is not only desirable but essential in order for the Association to progress. As George C. Brehm said in 1932, "Any organization that simply holds its own is really slipping back." What are the facts as to membership?

The growth was generally steadily upward until the peak was reached in 1917 with 1043 members. Then the number gradually decreased to 751 in 1925, increasing again to 830 in 1929. During the past ten years the figures as of September 1 for all grades are as follows:

1930	822	1935	779
1931	816	1936	761
1932	809	1937	783
1933	798	1938	798
1934	793	1939	791

It is evident that the membership is about stationary, which is not a satisfactory status. I would suggest that every member of this Association constitute himself a committee of one to bring in a new member every ten years, and by 1949 we will have a roster

of 1225 even after deducting all losses due to deaths, resignations and other causes, which at the present time amount each year to about 5½% of the membership.

In 1930, Robert Spurr Weston was concerned about the high average age of the members. I fear that this situation has not been improved. Perhaps a solution is to make a drive for junior members. The Constitution provides for this grade in the following words:

> "Art. II, Section 1. The Association shall consist of Members, Honorary Members, Life Members, Juniors, Associates and Corporate Members."

and again:

> "Section 5. A Junior shall be not less than eighteen years nor more than twenty-five years of age, and shall be a student in some engineering school or in active practice in some branch of engineering or water supply work. He shall be enrolled as a Member when he becomes twenty-five years of age."

At the present time there are only two Junior Members.

Papers and Journal. The papers that are of the most immediate interest to the members are not necessarily those that add most to the prestige of the Association through the JOURNAL. The reports of important committees and the compilation of water works statistics are examples of good material for the JOURNAL that are not so well suited to the technical program at the monthly meetings.

Papers to be read at the meetings should be of timely interest to the majority of those in attendance and accompanied by lantern slides or moving pictures where such diagrams, tables or pictures would add to the understanding of the subject. At least one paper for each meeting should be of a type to evoke a lively discussion.

With the morning Water Works School, Superintendents' Meeting, and Chemists' Session, the afternoon program should not be long enough to become tedious, preferably ending at about 4:30.

It is difficult to secure suitable papers, and I wish to pay my respects to the present Technical Program Committee for the excellent service that it has rendered during the past year. We are also indebted to those who have presented papers to the Association.

The value of the JOURNAL to the Association and to its members cannot be overemphasized. It should be the aim of the Program Committee to secure one or more papers each year for publication in the JOURNAL that are of such outstanding merit as to make every volume of the JOURNAL essential to all water works men.

The value of the JOURNAL is reflected in the number of pages

of papers printed each year. The record since 1929 for the September, December, March and June JOURNALS is as follows:

1929	405 pages	1934	457 pages
1930	*515 pages	1935	403 pages
1931	363 pages	1936	426 pages
1932	385 pages	1937	400 pages
1933	373 pages	1938	469 pages
		1939	438 pages

*194 pages Rainfall in N. E. by Goodnough.

In some of these years the report of a special committee or a paper on water works statistics accounts for a considerable increase in the number of pages. It would seem from the figures that the JOURNAL is being well maintained.

Meetings. The attendance at the monthly meetings is an index of the continued interest of the members in the affairs of the Association. The following table gives the monthly attendance at the luncheons so far as records are available. Some additional members and guests were often present for the papers.

Year	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total Nov. to Mar.
1929	124	157	125	165	182	182	—	853
1930	226	136	156	159	161	—	—	838
1931	138	157	179	169	168	—	—	811
1932	138	152	154	135	125	—	—	704
1933	120	128	130	152	109	182	—	639
1934	143	108	103	125	148	—	—	627
1935	138	—	—	—	—	—	—	—
1936	138	149	192	140	119	189	115	738
1937	187	172	154	179	148	—	—	840
1938	148	182	170	205	210	194	118	915
1939	164	179	192	185	178	156	152	898
Avge.	151	152	155	161	155	—	—	786

With a decreasing total membership in the last ten years, an increased attendance at the monthly luncheons and technical programs suggests that the Water Works School, Superintendents' Round Table, and Chemists' Round Table in the morning have been a helpful stimulus. The attendance at some meetings was influenced by severe storms, extreme cold weather and other factors. It seems as if the members of the Association are becoming more and more interested in these monthly meetings and the contacts that are made during the day.

The April meeting in southern New England and the May meeting in northern New England have been well attended, and it seems advisable to continue this custom. As George H. Finneran remarked, "If the members cannot come to the meetings, the meetings should go to the members."

Harry U. Fuller estimates that the members will normally travel one hundred miles to attend monthly meetings.

The June Outings are enjoyable occasions and should be continued. The place for this event must be selected with care both as to geographical location and available accommodations. The distance from Boston should probably be within a two-hour drive by automobile.

Annual Conventions. It is usually a very difficult undertaking to select the best place for the Annual Convention in September. The conventions have grown in interest and scope to such an extent that very few hotels can provide acceptable room accommodations and suitable facilities for the entertainments and meetings, in addition to the requirements for the exhibits by the Manufacturers' Association. Some of the questions to be considered are the location of previous conventions, distance from the center of membership, accommodations available, nearby points of professional, historical and scenic interest, and other factors that would influence the attendance and the enjoyment of the functions.

The center of membership, as per the 1936 list of members, based on member-miles, is as follows:

For New England: 20 miles west of Boston.

For New England, New York, New Jersey, and Pennsylvania: 20 miles east of Springfield.

For the United States: In the northwesterly corner of Connecticut, 9 miles east of the New York state line and 7 miles south of the Massachusetts state line.

The location and attendance at the conventions for the past twenty years is as follows:

	Date			Registration			
Year	September	Place	Hotel	Members	Associates	Guests	Total
1920	—	Holyoke, Mass.	—	127	83	167	377
1921	13-16	Bridgeport, Conn.	Stratfield	139	90	168	397
1922	12-15	New Bedford, Mass.	New Bedford	165	85	217	467
1923	18-21	Burlington, Vt.	Van Ness	—	—	—	—
1924	30-Oct. 3	Rochester, N. Y.	Powers	121	108	172	403
1925	8-11	St. Lawrence River	SS Richelieu	—	—	—	265
1926	14-17	Providence, R. I.	Prov.-Biltmore	207	117	270	594

1927	13-16	Boston, Mass.	Statler	244	132	270	646
1928	18-21	Montreal, Can.	Windsor	—	—	—	—
1929	17-20	Portland, Me.	Eastland	220	114	233	567
1930	23-26	Atlantic City, N. J.	Haddon Hall	142	113	126	381
1931	29-Oct. 2	Boston, Mass.	Statler	284	130	246	660
1932	27-30	Springfield, Mass.	Kimball	—	—	—	—
1933	19-22	Bridgeport, Conn.	Stratfield	163	100	154	417
1934	18-21	Boston, Mass.	Statler	212	114	204	530
1935	17-20	Providence, R. I.	Prov.-Biltmore	240	139	234	613
1936	22-25	New York, N. Y.	Pennsylvania	213	201	263	720
1937	22-25	Poland Spring, Me.	Poland Sp. Spa	214	154	187	555
1938	13-16	Boston, Mass.	Statler	265	165	259	689
1939	12-15	Montreal, Can.	Windsor	120	136	138	394

It is quite difficult to draw definite conclusions from this record because there have been some outside influences tending to add to or detract from the attendance, such as a year of prosperity or depression, weather conditions, and the interference of other conventions.

Our Secretary, Frank J. Gifford, has said that the time may soon come when the conventions will alternate between Boston and New York. At any rate, the registration has usually been the greatest when the conventions are held in one of these two cities.

Committees. This year there have been twenty-seven committees, with a membership of 106, actively engaged on various studies and reports. Several of these committees are joint committees with the American Water Works Association and sectional committees under the American Standards Association. Some others are standing committees engaged in the routine affairs of the Association, such as technical program, nominations, Dexter Brackett memorial medal, new members, finance and legislative. The importance of the committees cannot be overstated, and there should be no let-up in committee activities.

The Committee on Research and Water Works Practice, appointed this year, as recommended by Warren J. Scott in his presidential address, has an important function to perform. It is the duty of this committee to coördinate existing committees, to recommend new committees, to review committee reports, and to advise the Association on committee activities.

I would like to express my appreciation to the members who have so kindly agreed to accept appointment on committees during the past year.

Finances. I am pleased to report that the Association is in an excellent financial condition and that it is living within its income

and thereby setting an excellent example. The expenditures are guided by the budget recommended each year by the Finance Committee, after being approved by the Association at the Annual Convention. The gross expenditures for the ensuing year shall not exceed the total amount of the budget without a vote of the Association. The executive Committee may, however, by unanimous vote transfer unexpended balances from one account to another.

The following table shows the total receipts, expenditures and invested funds since 1929. The invested fund results from excess of receipts over expenditures from year to year and is all invested in Massachusetts savings banks. The fund amounted to $4,667.16 in 1910; $4,898.60 in 1915; $4,296.65 in 1920; and $8,622.43 in 1925.

Year	Total Receipts	Total Disbursements	Invested Fund
1929	$11,970.34	$11,628.99	$15,622.43
1930	11,625.62	12,414.19	15,622.43
1931	11,963.28	10,654.88	15,807.43
1932	11,341.02	10,573.50	15,807.43
1933	9,990.54	9,478.81	17,079.71
1934	9,518.06	11,178.10	17,079.71
1935	10,110.17	9,930.63	17,079.71
1936	10,725.15	11,611.11	16,379.71
1937	11,308.63	10,952.94	16,379.71
1938	10,387.54	10,205.58	16,379.71
1939	*12,458.54	9,170.33	16,379.71

*$1,564.00 from dues paid in advance.

In 1934, the office of the Association was moved from Tremont Temple to the Statler Building, and $1,113.50 were expended for furniture and fixtures. In 1936, $700 was withdrawn from the invested fund for printing the Constitution and a list of members.

Benefits to Members. It would be difficult to evaluate the benefits that the members derive from the Association on a monetary basis but when we consider the prestige of membership, the receipt of the JOURNAL, the privilege of attending the meetings and the annual convention, the knowledge and pleasure derived from intimate contact with other water works men, and the general feeling of satisfaction in being an integral part of a worthwhile organization, I am certain that the members are receiving full value for their investment in the Association and I have hope that the specific purpose of the Association, as set forth in the Constitution,—that is,

> "Its object shall be the advancement of knowledge relating to water works and water supply, and the encouragement of professional and social intercourse among water works men,"

is being partly realized.

Annual Report of the Secretary

Mr. President and Gentlemen of the New England Water Works Association: The Secretary submits herewith the following report of the changes in membership during the past fiscal year, and the general condition of the Association.

The present membership is 791, constituted as follows: 11 Honorary Members, 647 Members, 2 Junior Members, 110 Associate Members, and 21 Corporate Members. The detailed changes are as follows:

MEMBERSHIP

September 1, 1938.	Honorary Members, Total		12		
	Withdrawals:				
	Died	1	1	11	
	Elected	0		0	11
September 1, 1938.	Members, Total		657		
	Withdrawals:				
	Resigned	11			
	Died	12			
	Dropped by Executive Committee	19	42	615	
	Elected:				
	September, 1938	11			
	December, 1938	3			
	January, 1939	7			
	February, 1939	1			
	March, 1939	3			
	April, 1939	4			
	May, 1939	3		32	647
September 1, 1938.	Juniors, Total		0		
	Withdrawals		0		
	Elected:				
	November, 1938	1			
	April, 1939	1		2	2
September 1, 1938.	Associates, Total		107		
	Withdrawals:				
	Resigned	2			
	Dropped by Executive Committee	2	4	103	
	Elected:				
	September, 1938	4			

	November, 1938	1			
	January, 1939	1			
	March, 1939	1		7	110
September 1, 1938.	Corporates, Total		22		
	Withdrawals:				
	Resigned	1			
	Dropped by Executive Committee	1	2	20	
	Elected:				
	December, 1938	1		1	21
September 1, 1939.	Total Membership				791
September 1, 1938.	Total Membership				798
	Net Loss				7

ELECTIONS.

Members.

September 13, 1938.	Louis H. Alman, William Henry Doggett, Arthur Wellesley Harrington, Aram H. Hatch, Edwin Leon Jette, Thomas Edward Kennedy, Joseph M. Peirce, Lorrin Malcolm Pittendreigh, John Edward Riordan, David Rudolph Smith and Harold Morris Tarr. (11)
December 15, 1938.	Frederick Harold Miller, John H. Miller and Ellis A. Tarlton. (3)
January 19, 1939.	William T. Barry, Edward S. Brown, Jr., J. Vincentini Gutierrez, Edward F. Jerome, Edward C. Knight, Walter M. Hatch and Peter S. Sinclair. (7)
February 16, 1939.	David P. Geary. (1)
March 16, 1939.	Roger W. Moran, Patrick S. Nugent and Walter A. Peirce. (3)
April 27, 1939.	Ivan A. Buchanan. John L. Hayden, Thomas J. Rinaldo and Albert J. LePage. (4)
May 25, 1939.	Albert H. Fournier, Armen V. Garabedian and Frank Neiduski. (3)

Juniors.

November 17, 1938.	John Joseph Baffa. (1)
April 27, 1939.	John S. Bethel, Jr. (1)

Associates.

September 13, 1938.	International Filter Company, Keasbey & Mattison Company, E. & F. King & Co., Inc., and Water Leak Detector Company. (4)
November 17, 1938.	Youngstown Sheet & Tube Company. (1)
January 19, 1939.	Hill, Hubbell & Company. (1)
March 16, 1939.	Tate Pipe Linings Corp. (1)

WITHDRAWALS

Members.

Resigned: H. C. Crowell, Gail Phillips Edwards, Maurice E. FitzGerald, Edward A. McLaughlin, Louis T. McMahon, William H. O'Brien, James H. O'Connor, W. G. Starkweather, Ralph A. Wheeler, R. W. Wigmore, and Oliver E. Williams. (11)

Died: Frank E. Winsor, (Honorary Member) (1)
F. E. Appleton, Homer O. Blair, Allen W. Cuddeback, John C. DeMello, Jr., Patrick Gear, E. L. Grimes, Leigh I. Holdredge, Charles C. Hopkins, John W. Kay, Francis D. H. Lawlor, William Molis, Robert Ridgway. (12)

Dropped by Executive Committee: Frederick E. Babbitt, Allan S. Beale, Harry A. Burnham, Thomas H. Casey, Truman M. Curry, Jr., Arthur P. Gallant, Cecil C. Getchell, C. Nelson Harrub, Paul F. Kingman, Roger W. Macdonald, Howard C. Mandell, H. P. T. Matte, Wilfred J. Michel, Elias A. Mossey, Hermann Rosentreter, George H. Shedd, Robert P. Trask, Lincoln Van Gilder, and Harold Spry Woods. (19)

Associates.

Resigned: Walter W. Field & Son, Inc., W. & L. E. Gurley. (2)

Dropped by Executive Committee: Carson-Cadillac Corporation and Devonshire Arctic Chemical Company. (2)

Corporates.

Resigned: Town of Kingston, Mass. Water Commissioners. (1)

Dropped by Executive Committee: Lawrence (Mass.) Water Department. (1)

RECEIPTS FOR THE FISCAL YEAR, SEPTEMBER 1, 1938 TO SEPTEMBER 1, 1939.

Entrance Fees		$ 185.00
Annual Dues:		
Members	$3,167.25	
Corporates	200.00	
Associates	2,060.00	$5,427.25
Fractional Dues:		
Juniors	$ 3.00	
Members	53.00	
Corporates	5.00	
Associates	30.00	91.00
Past Dues:		
Members	$ 343.00	
Corporates	10.00	353.00
1939-1940 Dues:		
Members	$ 705.00	
Corporates	60.00	
Associates	800.00	1,565.00

Total Dues		$7,436.25
Dividends and Interests		387.92
Advertisements		3,398.60
Subscriptions		559.65
Journals		110.00
Reprints		181.96
Sundries		199.16
Total Receipts		$12,458.54
There is due the Association		
Entrance Fees	$ 6.00	
Dues	645.50	
Advertisements	379.00	
Journals	2.50	
Reprints	47.41	
Reblocking Electro	1.50	1,081.91
Total		$13,540.45

Respectfully submitted,

(Signed) FRANK J. GIFFORD, *Secretary.*

Annual Report of the Treasurer

President and Members of the New England Water Works Association:

I herewith submit the annual report of the Treasurer of the New England Water Works Association for the year ended August 31, 1939.

Statement of Cash Receipts and Disbursements
General Fund
For the Year ended August 31, 1939

Receipts			
Initiation Fees		$ 185.00	
Dues, 1938-1939 and Prior Years	$5,871.85		
Paid in Advance	1,564.40	7,436.25	
Interest		387.92	
From Publication of Journal			
Advertisements	3,398.60		
Subscriptions	559.65		
Sale of Journal	110.00		
Sale of Reprints	181.96		
Sale of Halftones, Electros, etc.	175.86	4,426.07	
Miscellaneous			
Membership Certificates	16.50		
Membership Lists	5.00		
Sundry	1.80	23.30	
Total Receipts			$12,458.54
Disbursements			
Publication of Journal			
Printing	2,113.33		
Plates	823.76		
Reporting	310.22		
Reprints	197.63		
Stationery and Postage	115.32		
Editor's Salary	500.00		
Sundry	59.04	4,119.30	
Office and General			
Certificates of Membership	14.46		
Secretary's Salary	400.00		
Assistant Secretary's Salary	1,350.00		
Secretary's Expense	82.33		
Treasurer's Salary	100.00		
Treasurer's Bond	12.50		
Printing, Postage and Stationery	331.96		

Office Rent	1,200.00		
Electricity	54.30		
Telephone and Telegraph	147.92		
Audit	65.00		
Sundry	151.97	3,910.44	
Forward		8,029.74	$12,458.54
Brought forward		$8,029.74	12,458.54
Meetings and Committees			
Badges	43.85		
Water Works School	128.50		
Printing, Postage and Stationery	534.05		
Stereopticon	18.50		
Convention Expense	203.49		
Travel Expense	126.97		
Sundry Expense	85.23	1,140.59	
Total Disbursements			9,170.33
Excess of Receipts over Disbursements, Exhibit A			3,288.21
Balance, General Cash, August 31, 1938			827.18
Balance, General Cash, August 31, 1939			
Represented by			
Cash in First National Bank of Boston		4,065.39	
Cash in Office		50.00	
			$ 4,115.39

STATEMENT OF ASSETS AND FUNDS

As at August 31, 1939

Assets

Cash in Banks, Invested Funds		
City Five Cents Savings Bank, Haverhill, Massachusetts	$2,000.00	
Farmers and Mechanics Savings Bank, Framingham, Massachusetts	2,068.46	
Franklin Savings Bank, Boston, Massachusetts	2,000.00	
Haverhill Savings Bank, Haverhill, Massachusetts	2,000.00	
Home Savings Bank, Boston, Massachusetts	311.25	
Mechanics Savings Bank, Reading, Massachusetts	2,000.00	
Pentucket Savings Bank, Haverhill, Massachusetts	2,000.00	
The People's Savings Bank, Worcester, Massachusetts	2,000.00	
Suffolk Savings Bank, Boston, Massachusetts	2,000.00	
Total Invested Cash		16,279.71
General Fund		
Cash, First National Bank of Boston	4,065.39	

In Office	50.00	4,115.39
Furniture and Fixtures		1,180.00
		$21,675.10

Funds

Invested Funds		$16,379.71
General Accounts		
Balance, August 31, 1938	$2,007.18	
Add Excess of Receipts over Disbursements, Exhibit B	3,288.21	
Balance, August 31, 1939		5,295.39
		$21,675.10

Note: The above statement is prepared on a cash basis and does not reflect the following:

Accounts Receivable, Dues	$ 651.50
Due on Account of Advertising and Other Miscellaneous Charges	430.41
	1,081.91
Dues Paid in Advance	$1,564.40

No depreciation has been taken on Furniture and Fixtures.

Respectfully submitted,

ABEL REYNOLDS, *Treasurer.*

Boston, September 6, 1939

ABEL REYNOLDS, *Treasurer,*
New England Water Works Association,
Providence, Rhode Island.

DEAR SIR:

We have made an examination of the accounts and financial records of the New England Water Works Association for the year ended August 31, 1939.

We submit herewith the following attached statements:

Exhibit A Statement of Assets and Funds as at August 31, 1939

Exhibit B Statement of Cash Receipts and Disbursements, General Fund, for the year ended August 31, 1939

In order to expedite preparation of the report, the cash book for the general fund was closed August 25, 1939.

We traced all recorded receipts into the depositary bank, verified the general fund bank account and petty cash fund as at August 31, 1939, and examined properly approved vouchers for all disbursements.

We also verified by direct confirmation the invested funds on deposit in savings banks.

Respectfully submitted,

SCOVELL, WELLINGTON & COMPANY

Annual Report of the Editor

To the New England Water Works Association:

The Editor submits herewith the following report for the year ending August 31, 1939.

As has been customary in the past, the tables of financial figures, accompanying the report, are based upon total charges and accounts receivable, rather than actual cash received or disbursed. A detailed statement of the receipts and disbursements on account of the September and December, 1938, and March and June, 1939, issues of the Journal is included in the Report of the Treasurer.

Table 1 is a statement of the material published.

Table 1.

Statement of Material in September and December, 1938, and March and June, 1939, Issues of the Journal of the New England Water Works Association.

Date	Pages of.								
	Papers	Proceedings	Total Text	Index	Advertisements	Cover and Contents	Insert Plates	Total	Total Cuts
September, 1938	120	0	120	0	39	5	0	164	43
December, 1938	88	34	122	10	39	5	0	166	19
March, 1939	115	5	120	0	41	5	1	167	31
June, 1939	118	18	126	0	42	5	0	173	23
Total	441	47	488	10	161	20	1	670	116

*Excluding reprints, the gross cost was $3,937.34, or $862.66 less than the estimate of the Finance Committee.

Table 2 gives a comparison of the Journal for the past year with preceding years.

Size. The four issues contained 670 pages, of which 488 were text.

Cost. The gross cost of the Journal was $4,119.30*, equivalent to $5.17 per member; the net profit was $306.77, equivalent to $0.39 per member.

Reprints. Reprints of each paper have been furnished to the author at cost.

Circulation. The present circulation of the Journal is:

Members, all grades	791
Subscribers	134
Exchanges	21
Total	946

(Journals have been sent to all subscribers.)

Respectfully submitted,

Gordon M. Fair, *Editor.*

TABLE 2.

COMPARISON OF JOURNALS OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	FOUR ISSUES FOR FISCAL YEAR ENDING AUG. 31.									
	1930	1931*	1932	1933	1934	1935	1936	1937	1938	1939
Average edition (copies printed) .	1,350	1,260	1,200	1,125	1,100	1,100	1,100	1,100	1,100	1,100
Average membership	822	816	813	805	796	786	770	772	785	795
Circulation at end of year	980	955	957	930	928	918	903	920	943	943
Pages of text	570	410	437	420	499	470	477	435	510	488
Pages of text per 1,000 members	693	502	537	522	627	598	619	561	650	614
Total pages, all kinds	812	682	644	594	645	643	642	627	699	670
Total pages per 1,000 members .	988	836	790	738	811	808	834	812	890	843
GROSS COST:										
Total	$8,054.59	$6,135.33	$5,024.03	$4,712.16	$5,411.30	$4,780.75	$5,880.68	$5,040.86	$4,658.05	$4,119.30
Per page	9.92	9.00	7.80	7.93	8.39	7.54	9.16	8.04	6.66	6.15
Per member	9.80	7.52	6.18	5.85	6.80	6.08	7.64	6.53	5.93	5.18
Per member per 1,000 pages ..	12.07	9.00	9.62	9.85	10.53	9.46	11.89	10.41	8.49	7.73
Per member per 1,000 pages text	17.19	18.34	14.30	13.94	13.62	12.93	16.01	15.01	11.63	10.61
NET COST:										
Total	$3,664.76	$1,252.21	$1,121.20	$1,176.77	$1,916.27	$1,332.99	$1,499.58	$489.13	$539.21	$306.77†
Per page	4.51	1.84	1.74	1.98	2.97	2.07	2.34	0.78	0.77	0.46†
Per member	4.46	1.53	1.38	1.46	2.41	1.70	1.95	0.63	0.69	0.39†
Per members per 1,000 pages ..	5.49	2.24	2.14	2.46	3.73	2.64	3.03	1.01	0.98	0.58†
Per member per 1,000 pages text	7.82	3.73	3.16	3.48	4.83	3.61	4.08	1.46	1.35	0.80†

*Including comprehensive index, 1882 to 1930. †Profit.

Report of Finance Committee

Executive Committee,
New England Water Works Ass'n.
Boston, Mass.

Gentlemen:

The Finance Committee submits the following Budget for the year 1939-1940:

Estimated Revenue

Initiation Fees	$ 150.00
Dues	5,600.00
Interest and Dividends	400.00
Journal	3,700.00
Miscellaneous	100.00
	$9,950.00

Expenditures

Office	$4,300.00
Journal	4,200.00
Committee Work and Meetings	1,300.00
Miscellaneous	150.00
	$9,950.00

In preparing the Budget, the expenditures for the past ten years were carefully reviewed. Adjustments were made for non-recurring income or expenditures and due consideration was given to any changes in activities of the association, after a discussion with the Assistant Secretary.

As usual, an audit of the books by certified public accountants will be found as part of the Treasurer's report.

(Signed) Walter P. Schwabe, *Chairman.*
Horace J. Cook,
H. L. Field.

Annual Report of Legislative Committee

September 1938—September 1939

Mr. President and Members of the New England Water Works Associations:

The Legislative Committee of the Association respectfully presents the following report of its activities during the year:

The personnel of the committee remained unchanged from last year.

In Massachusetts, some 2400 petitions were presented to the General Court but not as many as usual seemed to concern water works men. The attention of the members was called to four of these, and, although the petitioners were given leave to withdraw all of them, they seem worthy of mention inasmuch as they or similar bills will in all probability appear at the next session.

Senate Bill No. 161 was another attempt to require the employment of licensed engineers for 25 h. p. internal-combustion engines.

Senate Bill No. 35 was similar to No. 161, but would require licensed operators for derricks and cranes for unloading materials.

House Bill No. 332 asked for notice to the owner before water liens could be filed.

House Bill No. 1251 was an effort to force the Metropolitan District Commission to open Lake Cochituate to boating and fishing.

The Committee represented the Massachusetts members of the Association at three hearings and sent notice of one hearing to several members.

In Connecticut several bills of importance to water works operators were brought up, but it seemed that it would be unnecessary for this Association to present any opposition. These bills were mentioned at a meeting of the Association. Four of these bills were to open water supplies for bathing.

In the other New England states no bills presented appeared to be of importance to Association members.

Respectfully submitted,

(Signed) Sidney S. Anthony,
Percy R. Sanders,
George A. Reed,
Harold W. Griswold,
James J. Dillon,
Leon A. Goodale,
Stephen N. Taylor,
Arthur C. King, *Chairman.*

OBITUARY

Frank Edward Winsor

Died January 30, 1939

A truly representative memoir of Frank Winsor would bring into practically equal balance his fine personal characteristics and his outstanding work in the field of engineering. To summarize his life by a mere prosaic itemization of his professional accomplishments would be unfair and definitely incomplete. Even a casual acquaintance or infrequent contact with him revealed his personal charm; to enjoy his intimate friendship became a highly prized privilege.

Those for whom he worked had his unswerving loyalty, and soon came to respect the high ethical standards which were fundamental to all his undertakings. He had no patience with, nor place in his program for, political expediency; his plans and decisions were always based upon what he conceived to be sound engineering and in the public interest. Those who worked under him, whether in low or high capacity, were always "boosters" for their boss. Frank never seemed to forget that he too had begun at the bottom round, and that progress had meant long, hard work year after year. With the mediocre he showed unusual patience; for the earnest young man of promise there were many words of advice and encouragement. His carefully chosen engineering organizations were conspicuous for their smooth coördination. His relations with contractors on large projects were remarkably considerate, and consequently the work went forward with speed. Arrogance and the loud voice of command were traits entirely foreign to his nature.

Providence and Rhode Island seem to have been a nucleus around which Mr. Winsor's whole life centered. He was born in Johnston, R. I., November 16, 1870. In 1891 he received the degree of Ph.B. from Brown University; later the degrees of C.E. in 1892, A.M. in 1896, and in 1929 the honorary degree of Sc.D. from the same institution. He was encouraged to take up engineering for his life's work by his father, George Henry Winsor, a mechanical engineer. Incidentally, his great, great grandfather Israel Angell was a colonel in the Revolutionary War, and a descendant of Thomas Angell who came to Providence with Roger Williams.

In 1893 Mr. Winsor married Catharine Holbrook Burton in

Providence. There are three children: Lucy, Associate Professor of Economics at Wellesley College, and the wife of Hugh B. Killough, Professor of Economics at Brown University; Edward, a graduate of Dartmouth and Harvard Law School, and a well known practising lawyer in Providence; and Mrs. Hazen H. Ayer of Winchester, a graduate of Mt. Holyoke and of the New York School of Social Work.

Mr. Winsor began his engineering career in 1891 with the Metropolitan Sewerage Commission of Massachusetts, first as Transitman and later as Assistant Engineer. The work consisted mainly of preliminary surveys covering a considerable part of the Northern Metropolitan System, and of the construction of the Shirley Gut Siphon and the Deer Island Pumping Station.

From February to September, 1895, he was employed by Samuel M. Gray, Consulting Engineer of Providence, first in designing and later as Resident Engineer in constructing a sewerage system for Natick, Massachusetts. Association with Mr. Gray was to bear fruit later. He did not finish the sewer job, however, but left in October to join the staff of the Metropolitan Water Board of Massachusetts. For about 5 years he worked as an assistant in the Wachusett Dam and Reservoir and the Wachusett Aqueduct departments. Then he was promoted to be Assistant Engineer in charge of the Weston Aqueduct Department Office in Saxonville for 2½ years, and Division Engineer in charge of the construction of Division No. 2 of the Weston Aqueduct in Framingham and Wayland. This included about 2½ miles of masonry aqueduct and about one mile of 90-inch steel-pipe siphon across Happy Hollow.

The year 1903 found Mr. Winsor with the Commission on Additional Water Supply for New York, serving as Principal Assistant Engineer in charge of field investigations in the Aqueduct Department. In November he was called back to Massachusetts by the Charles River Basin Commission, successively as Division Engineer in charge of the design of dam, locks, flood control structures, etc., and as Principal Assistant Engineer. In 1906 the New York Board of Water Supply again demanded his services, first as Senior Division Engineer for nearly 4 years and then for 5½ years as Department Engineer in charge of the Southern Aqueduct Department. This work included about 31 miles of the Catskill Aqueduct and the Kensico and Hill View reservoirs. The great cost and difficult engineering problems involved made the job one of heavy responsibility. Mr. Winsor never lost touch with the work of the New York Board of Water Supply and for several years before his death he acted as one of its consulting engineers.

By 1915 Samuel M. Gray had recommended a new water supply for the City of Providence. The report was accepted, and Mr. Winsor was called in as Chief Engineer. The work involved the construction of a storage reservoir with a capacity of 37 billion gallons, requiring an earth dam with a maximum height of 100 feet above the ground and 180 feet above the rock, also 26½ miles of substitute highways and the establishment of a new cemetery. It also involved about 14 miles of aqueduct and pipe lines, including a small tunnel about 3½ miles long, a purification plant of 50 million gallons daily capacity, of the rapid filter type, also two covered distributing reservoirs. The new supply required an expenditure of about $21,000,000. Mr. Winsor very successfully carried the project through, and during its progress often remarked his happy relations with the Water Supply Board. The personal integrity and public spirit of the members of this group appealed strongly to him.

When there was need for major additions to the water supply sources of the Metropolitan Water District of Boston, Mr. Winsor was the outstanding candidate for Chief Engineer and was given the position. He commenced the work in October 1926. It consists of an extension westerly to the Ware and Swift rivers from Wachusett Reservoir which he, as a young man, had helped to build. The new Quabbin Reservoir in the Swift River Valley will have a capacity of 415 billion gallons, an area of 39 square miles and a length of 18 miles. The area is so great that it has necessitated relocating the boundaries of six towns and three counties, and wiping four towns out of corporate existence. It also required 36 miles of relocated State highways to replace existing highways in the reservoir area. The variety of the activities in which Mr. Winsor and his organization engaged can be appreciated from the fact that a new cemetery was required in which about 7,500 bodies, buried in the area affected by the reservoir, required reinterment. About 80,000 acres of land had to be acquired for sanitary protection and construction purposes in the reservoir area.

The gravity connection to Wachusett Reservoir is by a 24.6-mile tunnel which was practically completed in 1934. This tunnel passes directly beneath the Ware River Intake Works which were completed in 1931, and by means of which flood flows from the Ware River are diverted into the tunnel. Two earth dams will impound the waters of Quabbin Reservoir. The smaller dam, called Quabbin Dike, is 2,140 feet long, 135 feet high above the bed of Beaver Brook and 264 feet above the surface of sound ledge. Mr. Winsor completed it

in 1937. The larger main dam is 2,640 feet long, 170 feet high above the bed of Swift River and 295 feet above sound ledge, and will contain about 4 million cubic yards above the original surface. This dam was nearly completed at the time of Mr. Winsor's death, and the Water Supply Commission very fittingly named it "Winsor Dam" in his memory.

Mr. Winsor's work with the Water Supply Commission involved more than the Ware-Swift Project. He developed the Southern Sudbury system as an emergency supply, involving the construction of 7 miles of pipe lines. About three years ago he began an investigation for improvement in the distribution of water from the sources of supply of the District, with special attention to prevention of pollution in grade-line aqueducts. As a result of his work, the Legislature authorized construction of a pressure aqueduct to by-pass the Sudbury system and deliver the water directly from Wachusett Reservoir to the District, at a sufficiently increased pressure to eliminate much of the present pumping in the District. In these days when municipal contracts are almost certain to cost the full allotted expenditure or require extra appropriations, it is particularly significant to observe that Mr. Winsor was able to report an estimated saving of approximately 12 million dollars on the original appropriation of 65 millions made for the Ware-Swift extension. As the result of this remarkable achievement, the Commission was given permission to spend this sum, plus a large Federal grant, to take the necessary first steps in the aqueduct construction. Mr. Winsor proceeded to organize the work, and contracts totalling about $9,000,000 had been awarded, with some of them well under way, at the time of his death.

Through all his life's work, Mr. Winsor continued to attract to himself a host of friends among his engineering associates, contractors, and public officials. Indicative of the high esteem in which he was held, a complimentary dinner was given him in January, 1927, by the Affiliated Technical Societies of Boston.

Recently there was presented to Mrs. Winsor by the Metropolitan District Water Supply Commission a copy of a Memorial incorporated in their records, enumerating in detail the life and accomplishments of her husband, and closing with this fine tribute:

"The forty-seven years of service given to the public by Mr. Winsor, and the extensive works constructed under his supervision are a lasting memorial to his vision and industry. To his friends and associates his unlimited kindness and patience, his fidelity to all tasks

entrusted to him, and above all his faithfulness to what he conceived to be right, constitute his true imperishable memorial."

Mr. Winsor held membership in the following: American Water Works Association; Municipal Engineers of the City of New York, Director for one term; Providence Engineering Society, President 1922-1923; New England Water Works Association, President in 1927 and later Honorary Member; Boston Society of Civil Engineers, President in 1929; American Society of Civil Engineers, Director 1922-1924 and Vice President 1930-1931; American Academy of Arts and Sciences, Fellow; 32nd Degree Mason and Past Master; Sigma Chi and Sigma Xi Fraternities; Boston City Club; Brown Club of Boston, President in 1931; Trustee of Brown University; Brown Engineering Association, Honorary Member.

No longer can we enjoy Frank Winsor's hearty handshake or clap on the shoulder, the genial smile and the humorous retort, yet there forever remains with us who really knew him the magnetism of his friendship, and the influence of his example as a MAN, in the highest meaning of the word.

KARL R. KENNISON.
CHARLES G. RICHARDSON.